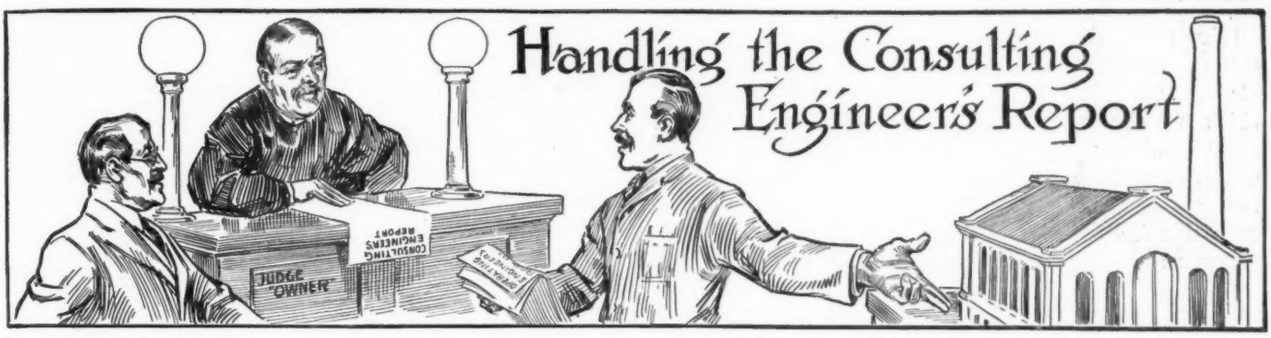
POWER

Vol. 44 NEW YORK, DECEMBER 5, 1916 No. 23

CANDID CHATS



ONE of the most difficult and important tasks that the operating engineer is ever called upon to perform is to analyze the report of a consulting engineer employed by the plant owner to investigate the economic desirability of shutting down the installation and purchasing central-station energy. The first impulse of many an engineer is to shrink from such a piece of work. It seems a good deal like asking him to verify his official death-warrant. In reality it is the highest kind of compliment to the operating engineer when his opinion is asked for on such a question. The right kind of an employer ought to give his engineer a fair chance to study the outside expert's report and to comment on or reply to it as occasion requires. It certainly takes courage to face the truth from the standpoint of the man whose job perhaps depends upon the correctness of the outside engineer's conclusions; but to the credit of the engineering profession it may be said that the willingness to look facts in the face, lead where they may, is one of its highest traditions.

No greater mistake could be made than to begin the study of such a report with the assumption that it must be gospel truth because the name of a noted expert is at the bottom of the page. The author may have a 42-centimeter mental caliber, and the report of such a "big gun" certainly is thunderous enough; but the question is whether the target is hit. It should never be forgotten that these types of intellectual artillery often operate at rather long range, and that the man on the job has at least the advantage of position. He is, or should be, supplied with just as good data as the other fellow, and upon the use of such material depends in no small degree the decision regarding the future of the plant. It is true that in America the value of expert opinion is under-rated by many, but this does not preclude the policy of making the expert set forth the reasons for his judgments, and it is these judgments that in the long run build reputations. Chairman McLeod of the Massachusetts Public Service Commission made an immensely significant statement recently in which he said that the old methods of settling rate questions by fiat had absolutely gone into the discard; that the public today demands a "show-down" of the facts and reasoning that lead the commission to its conclusions. Just how far the public is competent to pass upon expert judgment may be a question, but there is not the least doubt that an experienced operating engineer of the progressive type often is, and always should be, the best possible critic of an outsider's report on his installation.

Naturally, specific reports demand specific treatment, but all should be handled fearlessly and nothing taken for granted. The only way to successfully handle such a report as an outside consultant is apt to prepare is to consider it root and branch; to scrutinize every figure with a microscopic eye, noting everything that cannot be checked or that appears in the least degree abnormal; and then to follow through the reasoning in a manner that would make even a "Doubting Thomas" envious. To weigh everything, to test, balance, examine, compare, figure and inquire with 100 per cent. thoroughness is the proper plan of campaign. No engineer worthy of the title will wish to handle such a report in any but a scientific way, and he is entirely jusitfied in approaching it sceptically, not because his job may be tied up in the package, but because the burden of proof that a change in plant policy is financially necessary is upon the outsider. How it does stiffen one's backbone to realize this.

The consulting engineer may be a man of greater education and experience than the operating man, but this very increase in breadth of view often leads the outside expert into unsafe generalizations. He is tempted to apply the data and conclusions of the Middle West to the situation in eastern New York or Rhode Island, even when he is entirely unconscious of drawing an unwarranted parallel. Comparative data are indeed useful within their limitations, but it is a wise head that knows when the frontier is reached. Let the operating man, therefore, take the report from without and if in going through it "line upon line and precept upon precept" he finds anything that he does not concede or understand, let him note it down for return-fire ammunition. Let him keep a copy of his list of mooted points and then take it to his superior with or without his reply, and quietly but firmly insist that the outside authority be asked to explain or discuss these points one by one. Perhaps the aforesaid outsider will not relish having his report picked to pieces by a humble operating man or by the local plant engineer plus another expert adviser; but this is small reason for disquietude. There is no disgrace in asking for explanations, and the local engineer may rest assured that if he does not understand parts of the report his employer scarcely will either. And how can an intelligent decision be reached unless every word and figure in the report is properly appraised?

Let the local engineer, then, keep a sharp watch for unwarranted assumptions. Let him make sure that the figures that he gave the outside engineer appear to be properly used and arithmetically accurate, and let him pin Mr. Outsider close to the paper on his treatment of the heating problem and on his use of load-factors and fixed charges. If the latter allows 8 per cent. depreciation on the plant when local evidence favors 5 per cent. let the effect of such a difference be determined in the final casting-up of accounts. Surely there is nothing to be scared about in reading such a report if a grist of learned phraseology about sinking funds and unliquidated obsolescence, reproductive value, etc., be dragged into the argument to cover vaguenesses in allocating fixed costs. Force Mr. Consulting Engineer to defend his conclusions if they are found to be questionable, and seek the light of truth no matter where it leads.

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Pressure Tests of Welded Boiler-Tube Vessel

By Robert Cramer*

SYNOPSIS—Welded tube specimens tested with steam at 800 lb. pressure and 150 deg. superheat did not reveal weaknesses at the weld in any instance. Over 9,000 lb. per sq.in. water pressure were put on some of these specimens before they ruptured.

[Few doubt that welding will continue to find an ever-widening application to boilers and other pressure vessels. And it is but natural that owing to past experience, which has shown that it is most difficult to know how perfect and strong a weld is, welding for boilers should be looked upon with question and dealt with most cautiously, but somehow those with the widest experience and vision feel that welding applied to boilers will become a common practice. Some authorities have answered our request that they contribute to a symposium on the subject, and Mr. Cramer's article is a part of the symposium, some of which has already been published in *Power* for May 23, 1916, p. 724.—Editor.]

In the Winslow high-pressure boiler all joints in the furnace are acetylene-welded. When this type of joint was being considered for this purpose, no reliable tests were available to decide on its suitability. Since that time many of the joints have been in service, but before adopting them they were made to show the relative strength of the welds compared with the strength of the pieces of tubing which were welded together to form the vessel. All these joints are of one or two types. The first type is merely the capping or closing of the end of the tube. The second is the joint between a header and a small tube branching from it. In the test specimens, Figs. 1 to 10 inclusive, these details were made of the same size as the joints on the boilers.

The samples were provided with bosses for connection to a pressure-test pump capable of giving pressures up to 10,000 lb. per sq.in. This pump was provided with a gage calibrated before and after the test.

In carrying out the tests the samples were usually filled completely with water. Then the connection to the pump was made by ordinary ¼-in. extra-heavy pipe. An air space remained, ranging from one to three cubic inches under atmospheric pressure. All tests were carried to the point of rupture, and when rupture occurred, the expansion of the small quantity of highly compressed air caused a slight explosive action.

Fig. 1 shows a sample in which the heads are fastened by simply butt-welding them in accordance with the cross-section, Fig. 1-A. This sample was made to determine whether it was necessary to fold over the ends as in Figs. 2-A and 9-A. The sample burst at 8,500 lb., and the rupture crossed the weld. At the lower end the rupture tore into the weld, but this did not occur until after the rupture in the solid part of the tube had occurred.

Fig. 2 shows an improved arrangement. A tube of the same size as in the first sample before welding was forged over a recess of a specially machined head, shown in the sectional drawing, Fig. 2-A. At 6,000 lb. the weld at the boss began to sweat slightly. At the same pressure the tube began to swell slightly in the middle. At 8,000 lb. the swelling developed more rapidly and at 9,100 lb. the tube ruptured lengthwise. The end weld never leaked and apparently was not affected by the welding process.

The pressure of rupture, 9,000 lb., corresponds to a strain on the wall of the tubing of 69,700 lb. per sq.in. when referred to the original diameter of the tube. The fact that at the time of rupture the tube had swelled to a barrel shape made the actual strain somewhat higher.

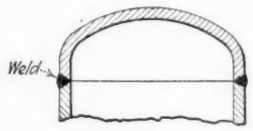


Fig. 1-A

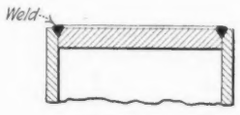


Fig. 5-A

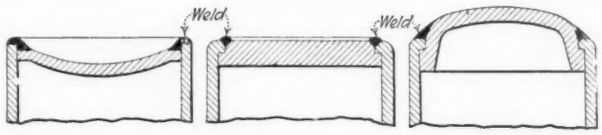


Fig. 3-A Fig. 2-A Fig. 9-A

SECTIONS SHOWING KINDS OF HEADS USED

This figure compares with the ultimate strength of the material used.

Fig. 3 shows a sample of seamless steel tubing 3¼ in. diameter, $\frac{3}{16}$ in. long, to which two dished-in heads were welded. The arrangement is shown in Fig. 3-A. It was interesting to note that with a pressure of about 2,500 lb. but one dished head bulged out, the action having the appearance as though the head were of rubber. This distortion strained the weld, which tore at 3,000 lb. per sq.in. The crack-like opening is shown at the top weld.

Fig. 4 shows a sample made like Figs. 9 and 9-A except that the welding is a little heavier and more metal has been added in the process of welding. This sample showed a slight swelling at the ends, but did not develop a leak until it ruptured. It began to swell slightly at the middle at 8,000 lb., and the rupture occurred at 8,500 lb.

A sample, Fig. 5, 3¼ in. diameter, $\frac{3}{16}$-in. wall, the ends inclosed by plain flat disks ⅝ in. thick, was welded the same as shown in Fig. 5-A. The sample was annealed before welding. The tube burst at 8,200 lb. after considerable one-side swelling had occurred. The welds were not injured.

Fig. 6 shows a sample which has on one end a head similar to that shown in Fig. 1 and Fig. 1-A, and on the other a head similar to that in Fig. 2-A and in the middle a girth weld merely butt joining two pieces of tubing. This sample was made of tubing 3¼ in. outside diameter, but only $\frac{5}{32}$ in. wall, and before testing it was annealed. At 7,900 lb. rupture of the tube occurred after considerable swelling in different places.

*Chief engineer Winslow Safety High-Pressure Boiler Co., Chicago, Ill.

FIGS. 1 TO 10. WELDED VESSELS MADE OF BOILER TUBES

Fig. 7 shows a sample annealed before testing. At about 7,500 lb. the tube burst as shown. While in this case the break extends into the weld, it did not start in the weld, but crosses it, which seems to indicate that the weakest point of the sample was not in the weld.

Fig. 8 shows a joint made between a 3¼-in. header with $\frac{5}{16}$-in. wall and a branch of 2 in. diameter of No. 11 gage tubing. This joint was welded in the same manner as the Winslow boiler tubes are welded into their headers. The three outward ends of the tubes were closed off with forged heads, butt-welded to the tube. This sample was annealed before testing. At about 6,400 lb. the large tube burst longitudinally near the weld without rupture extending into the weld.

Fig. 9 shows a sample made up in a similar manner to that shown in Fig. 2, except that the heads are dished outward. Fig. 9-A shows a cross-section of the head.

These tests seem to show definitely that acetylene welds of joints of this type tested can be made as strong as the tube itself. Sections of welds have been etched with a mixture of sulphuric and hydrochloric acid for about six hours, and a difference in appearance between the original tube and the added material was hardly discernible.

While all these results have been obtained with acetylene welding, similar tests made with electric welding seem to give uniformly good results. While electric welds seem to be as strong as acetylene welds, they appear to be poorer under pressures exceeding 3,000 lb. Many of the samples discharged sufficient water through a large number of very fine holes to prevent the pressure from being carried higher than 5,000 lb. per sq.in. One electrically welded sample shown in Fig. 10 seems to give exceptionally good service. In this case the heads were dished in, as shown at the left, and at a pressure of slightly over 3,000 lb. they bulged, as shown in the photographic section; but the weld remained intact. The original straight tube swelled into barrel shape. This last test was made at the shops of the Vilter Manufacturing Co., Milwaukee, Wis., whereas all the other tests were made at the works of the Winslow Safety High-Pressure Boiler Co., Chicago.

Safety-First Starting Apparatus for Electric Motors

By A. P. Danz

SYNOPSIS—A brief description of some of the safety-first equipment that has been developed for the control of electric motors.

A certain percentage of industrial accidents are due to negligence on the part of assistants or other workmen. Safety-first features have been developed to guard against such of these accidents as can be guarded against. For instance, it can be made impossible to start an electrically driven machine when it is being inspected or repaired.

A brief description of a few of the safety-first electrical devices which can now be obtained will best serve to bring out the various protective features. No attempt can be made in the short space of this article to cover the whole field, and the following should therefore be considered merely as a guide to indicate the trend of the times in design and not all that has been done along these lines.

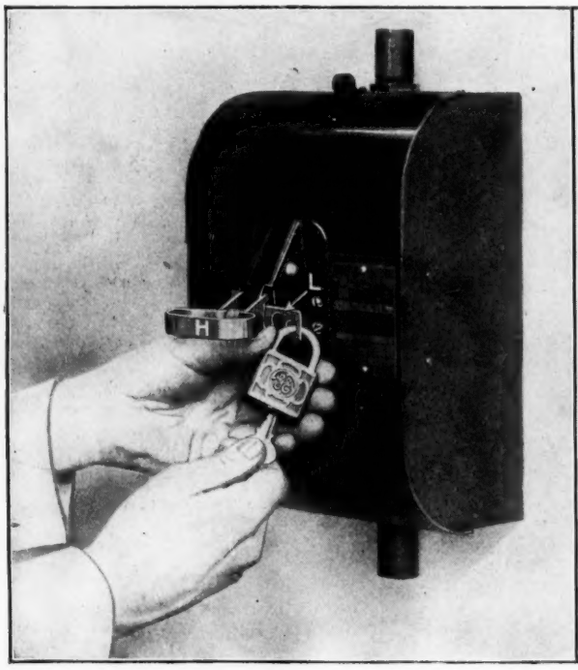


FIG. 1. SAFETY-FIRST KNIFE-SWITCH

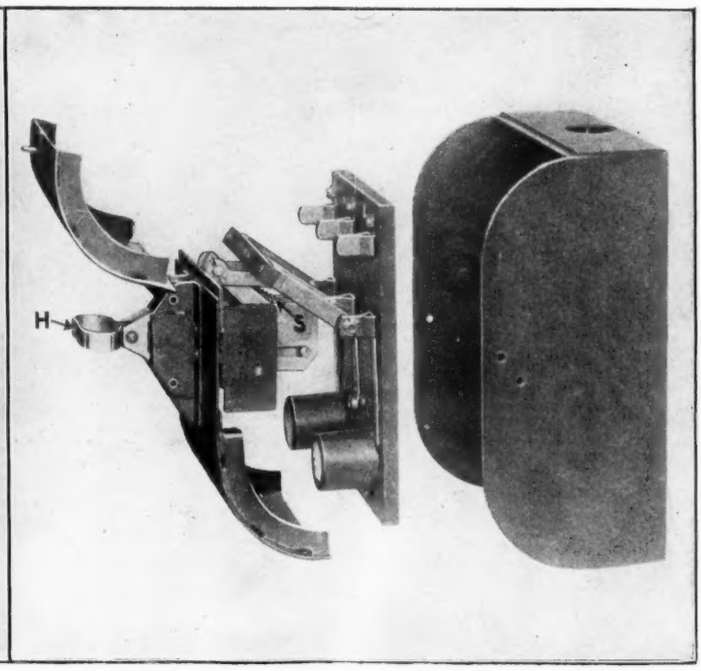


FIG. 2. SAFETY-FIRST KNIFE-SWITCH DISMANTLED

The inclosed switch shown in Figs. 1 and 2 was designed to take the place of the single-throw and double-throw plain, open-type, fused knife-switches which had been commonly used to start small squirrel-cage induction

motors by throwing them directly across full-line voltage. This device consists essentially of a three- or four-pole knife-switch with overload protective plugs, inclosed in a sheet-steel box provided with two spring-hinged covers, one over the switch and the other over the plugs, and is so arranged that the switch can be opened and closed by the handle *H* on the outside without opening the box. A spring-toggle mechanism *S*, Fig. 2, between the handle and the switch provides a quick make-and-break snap action, thus insuring long life for the switch contacts. The handle is pulled straight out to close the switch and is pushed in to open it. For ordinary operation, therefore, there is no cause for lifting the covers, and the operator can close and open the circuit without ever seeing or feeling a "live" part.

FIG. 3. INCLOSED SWITCH FOR D.-C. MOTORS

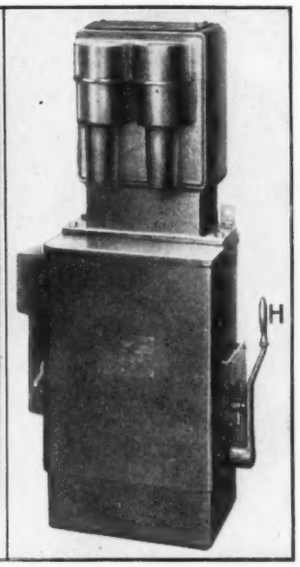


FIG. 4. SAFETY-FIRST COMPENSATOR

The designers did not stop there, however; they went a step farther to protect the inquisitive, hasty or careless operator. They interlocked the covers with the switch handle. When the handle is pulled out and all parts inside are "alive," the covers cannot be lifted; but when the handle has been pushed in, the covers are free to be opened. In this position of the handle the only "live" parts are the switch jaws under the top cover. Opening the lower cover to get at the protective plugs will therefore expose no "live" parts. But to keep unauthorized persons from touching the "live" jaws when the switch is open, provisions are made for locking the top cover. When the electrician puts on the padlock and carries away the key, the device is foolproof. The operator can start and stop the motor and change the plugs, but it is absolutely impossible to get a shock from the switch.

Another safety-first feature is that by inserting the locking plate as shown at *L*, Fig. 1, and padlocking it, the switch can be locked open and the covers both locked closed. So long as the lock remains, it will be impossible to pull out the handle. The workmen can therefore go ahead with repairs to the machine, feeling absolutely safe, as they know no one can start the motor unexpectedly.

With this switch it is impossible to start the motor accidentally by leaning something against it. In some types the operation of the handle is the opposite of that obtained in this device and accidental pressure on the handle would cause the switch to close. With the switch shown the only thing that can happen if something falls against the handle is the stopping of the motor if it is running, while if the motor is already at rest, nothing at all will happen.

Direct-current motor installations practically always require a double-pole knife-switch and fuses. When this is not furnished as a part of the starting panel, a separate safety switch, such as shown in Fig. 3, can be used. This consists of a standard-fused-lever switch inclosed in a cast-iron box. The switch is arranged for operation by means of the lever on the outside of the box. When the switch is closed and the fuses are therefore "alive," it is impossible to open the cover to get at the fuses. They can be reached only when the switch is open. If desired, the cover can be padlocked so that no one but the electrician can change the fuses. Provision has also been made for padlocking the switch open so that no one can start the motor unexpectedly when someone else is at work on the machine.

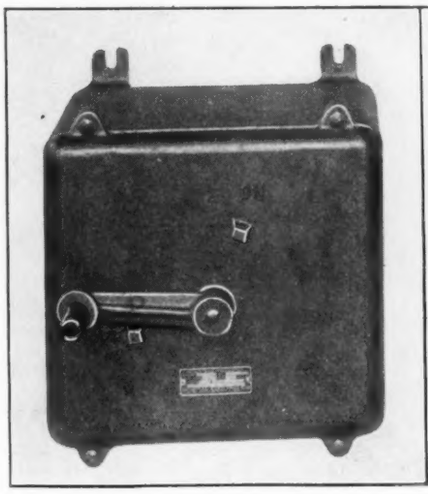


FIG. 5. TOTALLY INCLOSED STARTING BOX

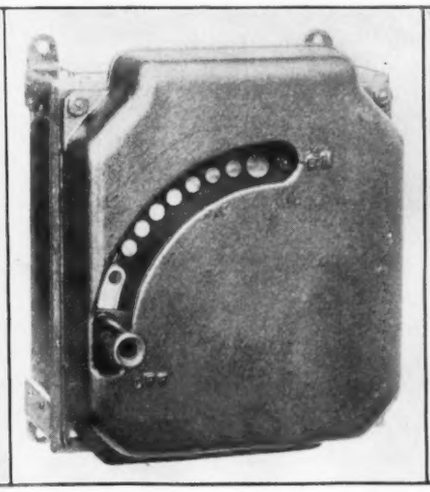


FIG. 6. STARTING BOX EQUIPPED WITH PROTECTIVE COVER

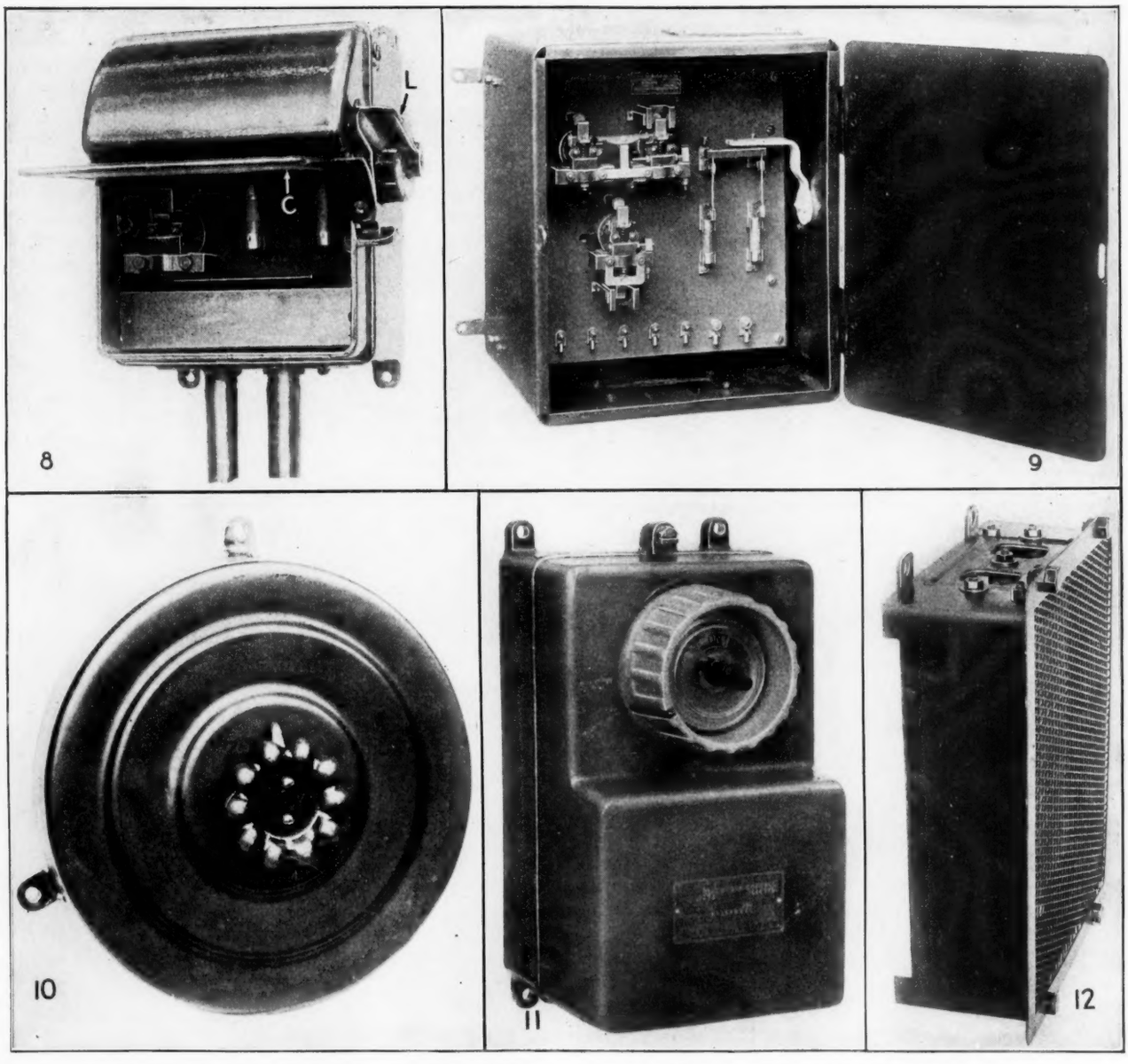
FIG. 7. PUSH BUTTON IN CAST-IRON BOX

For starting squirrel-cage induction motors that cannot be thrown directly across the line, the form of starting

compensator shown in Fig. 4 makes a good installation. Here, again, all current-carrying parts are fully covered. In this type the power lines come into the box in conduit and the lines between the motor and the box are also in conduit, so that there is no exposed wiring anywhere about the installation. The switch is immersed in oil and is operated by means of the insulated handle *H* on the outside of the case. The operator is therefore fully protected when starting. For protection when working on the machine, a special locking handle may be provided. This device differs from the ordinary handle in being provided with a removable pin, a hasp and a padlock and eye-bolt to hold the hasp in position. For ordinary operation the handle is perfectly free to move, but when locked, the pin engages a projection on the side of the compensator case and the handle cannot be moved.

For direct-current motors it is possible to obtain starters totally inclosed in tight cast-iron boxes with handles operating the inner switch from the outside. One of these is shown in Fig. 5. As this design affords no ventilation, the resistance has to be made relatively heavy and the cost becomes unnecessarily high for all installations where an absolutely tight box is not required. For simple protection of the operator a slotted cover can be obtained; Fig. 6 shows one of these installed on a common hand starter. It will be noticed that while the contacts are visible through the slot, the "live" parts are all effectively covered for normal operation and the only possible way one could get a shock would be to deliberately insert his fingers in the slot.

Where hand starters are provided with low-voltage-release magnets, it is becoming quite common to find safety-first push-button emergency stop stations in use. This applies to alternating-current as well as to direct-current installations. One or more push-buttons are connected in series with the low-voltage-release coil so that when the



FIGS. 8 TO 12. SHOW DIFFERENT TYPES OF SAFETY-FIRST CONTROL APPARATUS

Figs. 8 and 9—Direct-current motor self-starters installed in metal boxes. Fig. 10—Small field rheostat equipped with a protective cover. Fig. 11—Safety-first controller for use on small headstock lathe. Fig. 12—Resistance unit for wound-rotor induction motor fitted with an expanded metal cover.

circuit is broken at any push-button, the starting handle will be released and the motor stopped. The stations are located handily around the machines, where they can be reached quickly in case of emergency. They are frequently used with line-shaft drive, one or more stations being located on each machine of the group. They are used most widely with machines where there is a chance for the operators to get their fingers caught. The station shown in Fig. 7 contains a momentary-contact button. Normally the circuit through the button is held closed by a spring contact. When the button is pressed, the circuit is broken, but when released after the starting handle has been tripped, the circuit through the button is restored. The cast-iron push-button box is arranged so that the conduit can be screwed into it, thus eliminating exposed wiring.

Push-button operated self-starters are coming into wider use every day. This is because of the actual savings in maintenance and the speeding up of production which follow their installation. There is such a wide variety of types that only a few of the safety features will be pointed out.

Self-Starter as a Safety-First Device

The self-starter is inherently a safety-first device, because the starter proper is usually mounted in some out-of-the-way place where no one would be likely to touch it. The operator touches nothing but the push-button station or inclosed master switch, and so has no chance of getting a shock except when he goes to the panel to operate the knife-switch or to replace fuses. To protect the operator when at the panel, some of the starters are inclosed in special cases and provided with levers on the outside of the case for opening and closing the knife-switch.

Fig. 8 shows a self-starter for small direct-current motors that fully protects the operator. Normal operation is from a push-button, but if the operator wants to make the motor "dead," he throws the lever *L* on the outside of the box, thus opening the double-pole knife-switch. The cover *C* over the lower half of the box, when lifted as shown in the figure, permits access to the fuses. The cover is interlocked with the switch lever in such a way that the box cannot be opened except when the lever arm is in the off position, as shown, and when all accessible parts inside the box are "dead." With the foregoing equipment it is also possible to padlock the lever arm in the off position so that the motor cannot be started unexpectedly.

A starter for larger direct-current motors is shown in Fig. 9. Owing to size it is impractical to interlock the cover of the box with the knife-switch, but it will be noticed that the box can be locked so that no unauthorized person can tamper with the adjustments of the contactors and incidentally get burnt. By means of the lever on the outside of the box, the operator can turn the power on or off at will without ever seeing a "live" contact.

On many machines where direct-current self-starters are used, speed adjustment is required, and to obtain this, field rheostats of some type are used. Fig. 10 shows a common round-plate rheostat, but a sheet-metal cover has been snapped over the buttons and contact arm, so that when the operator reaches for the handle without looking at it, he cannot by any chance touch an exposed current-carrying part.

When starting a machine or changing its speed, the machine should be watched. But if the operator has a box with exposed "live" parts, he will watch the starter instead of the machine. Covering the contacts abolishes fear and insures better attention to the machine, therefore safer starting.

The safety-first controller shown in Fig. 11 is for use on small headstock lathes. It embodies numerous valuable features in a small space. Speed adjustment is provided, but the handle of the regulator is interlocked so that the motor always starts with full field strength. The controller provides overload and low-voltage protection and a snap-switch or push-button stop. It is arranged for conduit wiring, and every "live" part is covered.

With all the larger slip-ring or wound-rotor induction motors it is now common practice to use, for both starting duty and speed regulation, a drum type of controller. The starting or regulating resistance that goes with the drum controller is usually furnished in individual frames, which can be stacked one on top of another. In some cases these sections can be mounted in some out-of-the-way place where no one will touch them, but generally this is not possible, and to obtain protection covers like those in Fig. 5 are used. The sections are stacked to the desired height, and the top section is then fitted with the expanded-metal cover. Sheet-metal covers are bolted on each side of each section, or on only one side of each section, if the resistance is set so that the other side is against a wall or machine.

In most every case in the foregoing the safety feature is obtained, as in a great many other applications, not so much by the use of any particular new device as by using relatively new schemes of interconnecting older standard apparatus. Each plant has its own peculiar conditions to be met, and a general recommendation of any particular type of control is therefore impossible. Each individual installation should be carefully studied if the right apparatus is to be obtained. In general, however, it has become an accepted rule that equipment should be installed that provides the maximum of safety to the operator, because it will produce the biggest returns in machine efficiency, in man efficiency and in good will.

The Spaulding Development—According to the "Journal of Electricity, Power and Gas," the Spaulding Development on the Bear River in California will comprise seven power houses and will utilize a total head of 4,306 ft. The dam at Lake Spaulding when completed will be 305 ft. high, making it the highest in the world. The power plant at the dam will develop 6,000 kw. What is known as the Drum power plant is located 9.6 mi. from the Spaulding dam and develops 50,000 kw. working under a 1,375-ft. head. No. 2 power plant is 8.5 mi. farther down the river and when completed will generate 25,000 kw. operating under a head of 826 ft. No. 3 plant is 7 mi. from No. 2, will use a 500-ft. head and will be of 15,000 kw. capacity when completed. Power house No. 4, known as the Halsey power plant, is 27 mi. from No. 3 and is nearing completion, when it will develop 12,500 kw. working under a 331-ft. head. In No. 5, or as it is called, the Wise power plant, which is 7.5 mi. from the Halsey plant, is installed a 20,000-hp. single-discharge turbine, the largest unit of the kind in the world. It will operate at a speed of 360 r.p.m. under a head of 519 ft. The unit weighs 185,000 lb., and is direct-connected to 15,000-kw. generator. No. 6 power plant is situated 4 mi. from No. 5 and will develop 10,000 kw. working under a head of 450 ft. In 63.6 mi. of the river a fall of 4,306 ft. will be used when the development is complete, and will generate 133,500 kw.

To Change the Speed of a Corliss Engine the governor should be pulleyed so that it will run at the old speed—the speed for which it was intended. A little departure from this speed will keep it against one or the other of its stops.

Prof. John E. Sweet--The Man

The death of John E. Sweet has brought out a number of personal reminiscences by the "boys," to whom he was both "Professor" and personal friend. One of them, J. E. Johnson, Jr., has written at considerable length in the *American Machinist* regarding his acquaintance with the professor and the incidents in the life of this remarkable character. These reminiscences, in part as follows, are particularly appropriate at this time in view of the fact that on Wednesday, Dec. 6, the American Society of Mechanical Engineers will hold memorial exercises in honor of its past president, John E. Sweet.

It was perhaps the most significant phase of Professor Sweet's character that men once thrown in contact with him, even if not very intimately, retained a vivid recollection of him and a desire for more of his companionship. This was partly because of his personal charm and partly because of the generosity with which he gave himself, to whoever might ask of him, without any question of the right of the person asking the favor, but simply on the ground that that person asked his assistance. The following incident well illustrates this trait.

On the last day of Professor Sweet's life a man from Texas—a total stranger—came to ask advice about a new type of engine governor. The professor spent the whole forenoon with his visitor, but was seized at three o'clock with the attack that ended his life. He went home, but before his death at eight he found time to telephone the office concerning further information that must be given to the stranger when he returned. This act was characteristic, and it was therefore not surprising that he bound to himself, with ties dissolved only by death, a considerable number of the men with whom he had contact in the course of his long life. To all those who sought what he had to give, he gave freely, and in later life, I think, he made in his own mind very little distinction between the "Straight-Line boys" and the "Cornell boys." Others, as they came somehow to know and to love him, were taken into the fold.

Annual Dinners in Honor of Professor Sweet

The first of what became known as the annual Sweet dinners was held as a surprise one evening during the latter part of the week of the New York meeting of the American Society of Mechanical Engineers in December, 1901. The dinner was held at the old "Arena." The professor had planned to go back to Syracuse the afternoon of the day for which the dinner was set, but Mrs. Sweet, who was taken into the confidence of the "boys," discouraged the idea and Mr. Armstrong persuaded him to stay over to help "talk to some men to whom he (Armstrong) wanted to sell an engine." We all gathered in a reception room adjacent to the dining room, at an early hour, and Armstrong then brought the Professor in to meet the men who were "to buy the engine." His surprise and delight in meeting again these men, many of whom he had not seen for twenty years or more, was something that will always be one of the pleasant recollections of my life. He went around the room greeting each one in turn with equal delight, but with varying degrees of surprise in the different cases. After the greetings were over, we adjourned to the dining room, where the dinner was served. At the conclusion in a few well-chosen sentences Mr. Halsey presented a specially designed watch to the professor "as a token of our affection and esteem." The old gentleman had been having as much fun as anybody out of the proceedings, but that was too much for him. He arose to his feet with the tears streaming down his cheeks and said, "Gentlemen, I had expected to make a few remarks, but I cannot," and sat down. We sat around and talked till a late hour, and it was unanimously voted that the meeting was such a great success that we should hold one every year, and this was accordingly done.

Every year, with the exception of 1911, when Professor was on a trip around the world, a fair-sized company of the "boys" met at dinner to do him honor. In 1912, on the occasion of Professor Sweet's eightieth birthday, Oct. 21, the American Society of Mechanical Engineers gave him a large dinner party in the United Engineering Building in New York.

His Keen Sense of Humor

Very often a man with high ideals of conduct is spoiled for human companionship by a sense of dignity that replaces or stifles his sense of humor. It was far otherwise with Professor Sweet. He had a keen sense of humor and could illustrate his point with a short story or a witty saying in a manner characteristically American, and a good story well told was sure of at least one appreciative hearer when he was present.

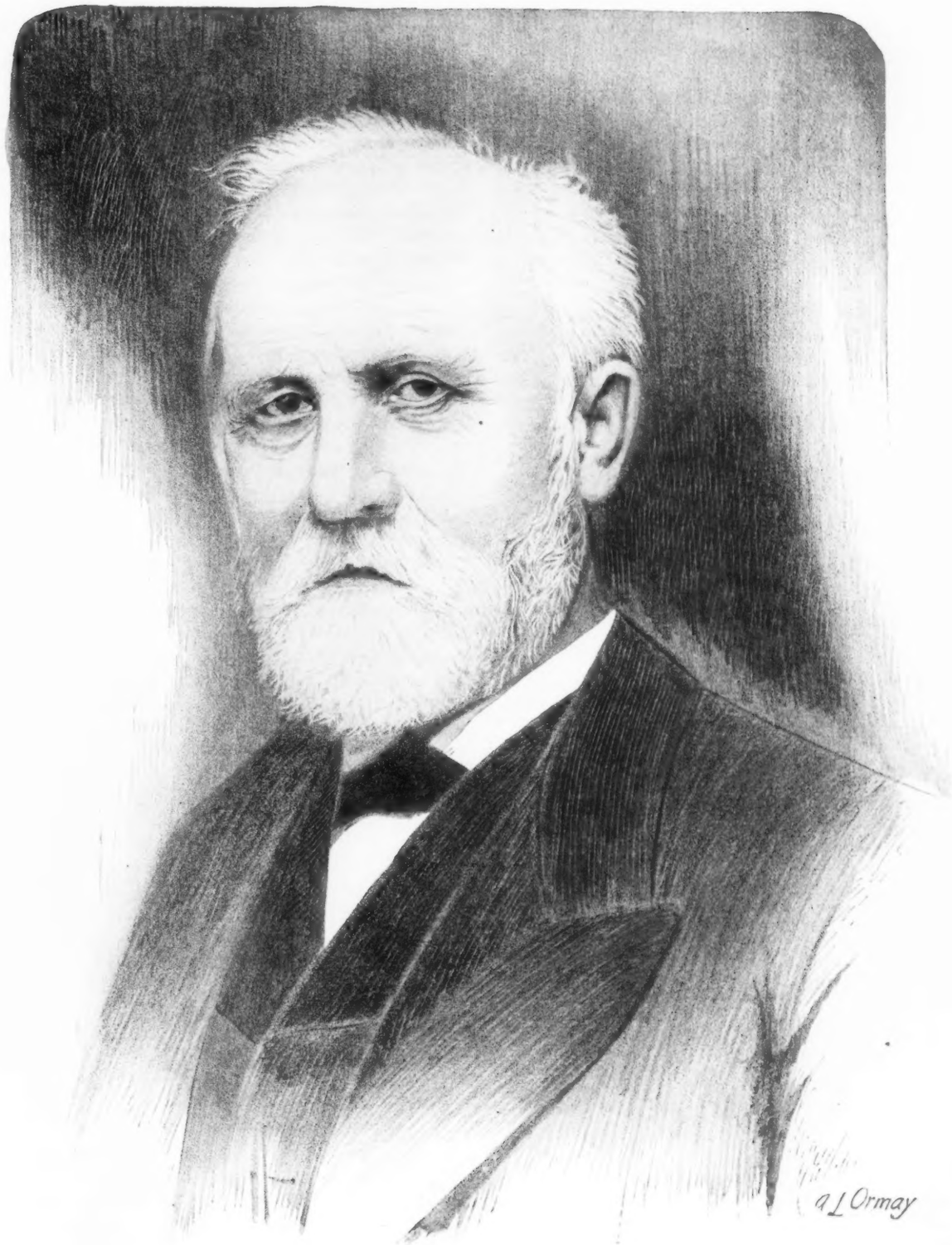
Here again, perhaps, his modesty played a big part. He was never in his own mind a king amid inferiors, but one of a group from each of whom he could learn as eagerly as they could learn from him. This trait kept up his spirit of fellowship and made companionship agreeable, and leadership natural, to him.

Some of Professor Sweet's Achievements

As to Professor Sweet's great works, little can be said that the engineering profession does not generally know. At Cornell he had charge of the mechanical end of the first "dynamo" built in America, of which Professor Anthony designed the electric end, and he started there the manufacture of micrometer calipers, which he called "measuring machines," because he preferred the simple English name for everything. He also began there the making of limit and standard gages of hardened and ground steel, such as are now common, but at that day were scarcely known. He not only had these gages made by the students, but he literally fathered their general introduction into shop practice, as well as that of many other mechanical refinements now in common use, but too numerous to mention here. A notable feature of his designing was that he achieved results by leaving things off rather than by putting them on. If somebody had accomplished a given result through the use of a lot of moving parts, he would scheme some simple way whereby the same result could be obtained with the aid of one or two parts.

The Artistic Quality of His Designs

Another feature of Professor Sweet's designing, which in a sense was connected with that last described, was his tremendous artistic sense. He had entered engineering through architecture and had realized fifty years ahead



John E. Sweet.

of the rest of the American world that true art in architecture consists of a harmonious adaptation of the means employed to the end desired, not in the addition of superfluous parts for purposes of ornament only. He believed, and rightly, as we now know, that art in machine designing consists in the most direct and harmonious adaptation of the means at hand to the object desired. The fluting of columns, the ornamental paneling of flat surfaces and the like, the use of curves where a straight line would serve and, above all, where a stress was to be transmitted were customary in machine designs only twenty or thirty years ago, but they were all abominations in the professor's truly artistic sight. In matters of appearance, as well as in the mechanism used, he believed in the harmonious assembling of the essential and the absolute elimination of the unnecessary.

This is so much a feature of the best present-day designing that those familiar only with the present do not realize how different were the conditions previous to Professor Sweet's precepts and example concerning the beauties of simplicity. He had a saying, "Whatever is right, looks right"; and if something looked wrong, he would analyze it until he found what the wrong was.

Engine Design Embodied Advanced Features

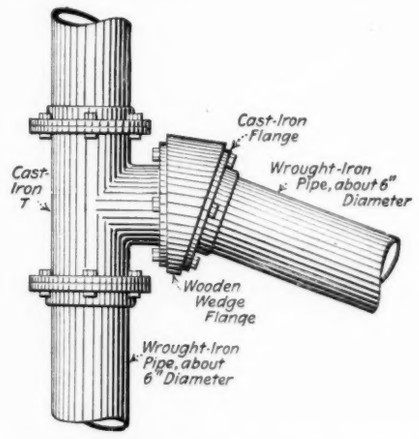
Some of the details of the Straight-Line engine tell how remarkable was the workmanship and how radical was the design as compared with previous practice. At the time I was there, now nearly twenty-five years ago, he was using hardened and ground bushings for the valve gear, so that if a pin became worn, its bush was knocked off and a new one put on, while if the bore became worn, its bushing was knocked out and a new one inserted. In this way the life of these parts was indefinite. The main-bearing shells were solid, but had eccentric check pieces of hard babbitt fitted inside them so that rotating up these check pieces by liners behind the thick edge took up the wear, but left the center of the bearing surface unchanged. The valve stem was a bush of hard babbitt about two feet long, hand-reamed to an exact fit on the ground valve stem. The babbitt bush was held in a gland, so that it could accommodate itself to the line of the valve stem; the piston-rod packing was the same, except much shorter. This construction made an absolutely tight joint, which was good for years without any adjustment whatever and with an irreducible minimum of friction. Special trams were invented, which centered themselves to the actual bore of the cylinder and permitted the main-bearing shell seats in the frame to be bored accurately at right angles to the center line of the cylinder.

Professor Sweet made a study of the action of oil in moving machinery; and when the Straight-Line engine was built, it was an engine with the lubricating system built into it instead of being an engine with some oil cups stuck on it. It is probable that the system of lubrication, which was an inherent part of that engine twenty-five years ago, has not been bettered since. He not only devised simple ways to make the oil go where he wanted it to go, but equally simple ones that prevented it from traveling where he did not want it to go—for instance, the knife-edge rings mounted on the shaft close to the ends of the main-bearing shells and inside of hoods cast in the frame, which caught the oil thrown off by the knife-edges and returned it to the oil cellar in the base of the main bearing. These things are simple and obvious enough when they are once done, but those whose memory goes back so far will remember what a huge step in advance they constituted over anything that had been done up to that time.

When all is said and done, while I do not believe that the world knows now half that Professor Sweet did for the furtherance of mechanical engineering in its broader sense, nevertheless it seems that his character exceeded his achievements. As a moral force in the world he was greater, because rarer, than his achievements. I can never forget his modesty, his absolute unselfishness, his helpfulness without thought of the cost to himself, and the way he never preached, but unfailingly lived, the golden rule. To these things must be added his *human* personality and his magnetic power of attracting to himself a large percentage of the men he met, of holding their interest and affection for long years, generally for life, and of inspiring them with high ideals of conduct without ever mentioning the subject. Remember, too, his marvelous ability to instruct men technically and to broaden and simplify their methods of thought. These seem to me to be the characteristics which, possessed by a man whose achievements equal those of the greatest engineers of our time, put him upon a pedestal so that he overtops them all in those things that truly make for greatness.

A Wooden Angle Flange

In the concentrating mill of the Old Dominion at Globe, Ariz., an ingenious method of making a pipe connection at an angle without the use of special fittings, which cost money and require time, was devised as shown in the sketch. By simply cutting a wooden wedge to fit snugly



A WOODEN ODD-ANGLE PIPE FITTING

between the flanges, drilling, boring and trimming the outside and using the customary bolts and gaskets, a perfectly tight and satisfactory job was secured.—*Engineering and Mining Journal.*

Round versus Rectangular Wire—Round wire, because of its freedom from trouble in rewinding motors and the ease with which it may be secured, is preferred by many. A study of the cost of machines wound with round wire indicates that they cost about 2.5 per cent. more than those wound with rectangular conductors. When certain sizes of rectangular wire become standardized, as is round wire today, and when winders become more familiar with its use, the indications are that a great deal of the argument against it will disappear.

Operation of the Pasadena, Calif., Municipal Plant

The municipal light and power plant of the City of Pasadena, Calif., has made an enviable record during its eight years of operation. The station has effected a total saving to local residents of about $900,000 in light and power alone, or more than the cost of the entire plant and system, which represents an investment of approximately $500,000. The station has a present valuation of $770,000. Bond issues aggregating $327,000 have been reduced by $60,025 from the earnings of the station, which have also been sufficient to provide for improvements and extensions, as required, to a total amount of $258,200.

Since the city actively entered the local field, the rate for electric lighting has been reduced from 15c. to 5c. per kw.-hr., with a minimum meter charge of 50c. a month. The rate for service, reduced from time to time, has been based upon the existing number of consumers, it having been conservatively estimated that when 4,000 active accounts were obtained, the 5c. rate with a sliding scale of reduction for increased consumption could be profitably maintained. This rate is particularly remarkable when it is considered that it is 29 per cent. less than the current lighting charge, in neighboring sections, of the public-utility company operating in competition with the municipal station and having extensive hydro-electric plants as against the isolated steam-operated city plant.

In October, 1908, a lighting rate of 8c. per kw.-hr. maximum and 5c. minimum for large consumers, with a monthly minimum charge of 80c., was established. About a year later (in December, 1909) the maximum rate was reduced to 7c. and the minimum to 3c., with the same minimum monthly charge. In September, 1910, the present lighting rate of 5c. maximum was put in force, the minimum charge of 3c. remaining as before, and the minimum monthly rate was reduced to 75c. This monthly charge has later been reduced, in May, 1913 and 1914, to 60c. and 50c. respectively.

The following tabulation is interesting in affording a brief summary of the financial status of the station since the beginning of operation, showing the constant increase in surplus over the operating expenses each succeeding year:

Fiscal Year	Revenue	Operating Expenses	Surplus
1907–8	$23,425 64	$17,688 71	.....
1908–9	45,875 76	21,431 73	$1,261 49
1909–10	74,935 32	36,068 56	8,140 47
1910–11	100,011 10	56,570 95	17,149 67
1911–12	123,485 11	63,700 30	18,628 78
1912–13	138,889.41	70,073.45	23,558.09
1913–14	176,431.30	96,641.66	29,360.92
1914–15	193,505.11	100,945.34	37,246.23

With a total generating capacity of 3,000 kw., the station has been serving about 5,000 consumers, and to provide for an increase of over 3,000 new users, a 3,300-kw. steam turbine has recently been installed. The station equipment comprises a battery of Stirling water-tube boilers, a 2,000-hp. cross-compound condensing engine, a Parsons turbine of the same capacity and the new turbine unit before noted.

About 6,000 poles, ranging from 15 to 60 ft. in height, carry transmission and service lines over a total of about 200 mi. of territory. The station has about 9,000 service connections requiring over 8,000 meters, with a capacity equivalent to about 8,800 kw.-hr., and approximately 700 transformers, with a capacity equivalent to 6,800 kw. About 70 employees are required for the operation of the plant, distributing system and other features of service.

The following data, compiled by C. W. Koiner, general manager of the station, covering the last fiscal year, set forth the statistics regarding the operation of the plant. This was the most successful year in the history of the enterprise and indicates still further possibilities.

STATION AND SYSTEM OPERATION

Output, kilowatt-hours	5,866,358
Kilowatt-hours per barrel of oil	134.26
Production cost of electric energy generated	$0.00763
Production cost of electric energy sold	.00952
Distribution cost of electric energy sold	.01196
Interest cost of electric energy sold	.00531
Depreciation cost of electric energy sold	.00646
Total cost of electric energy sold per kw-hr	$0.03325
Operating expenses, 52.2 per cent. of gross income.	
Meters in operation July 1	7,755
Average number of meters in operation during entire year	7,326
Efficiency of distribution system, 80.93 per cent.	

The following table gives comprehensive information regarding the output of the station and distributing system during the same period, embracing important phases of operation not included under the head "Station and System Operation":

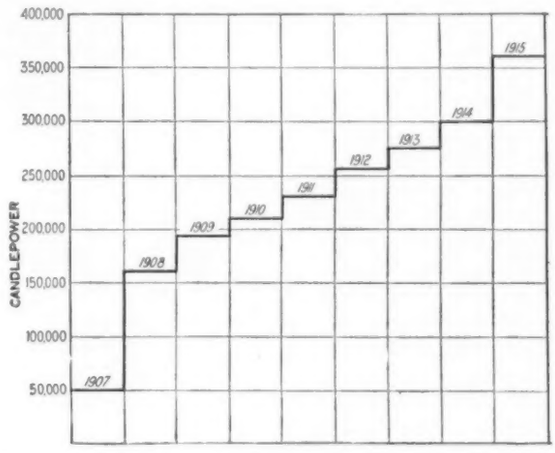


FIG. 1. TOTAL CANDLEPOWER STREET-LIGHTING SYSTEM

	Output, Kw.-Hr.	Receipts per Kw.-Hr.
Street Lighting		
Clusters and alleys	398,159	$0.03421
Arcs and series tungstens	810,699	.04701
	1,208,858	.04279
Commercial System		
Lighting, including city departments	2,253,960	.04932
Power, including city departments	1,237,762	.02461
	3,491,722	.04056
Total electric energy sold	4,700,580	.04114
Lighting at plant	32,028	
Lighting at office and stockroom	14,789	
	46,817	
Core loss of transformers	355,973	
Shunt loss of meters	128,213	
Copper and transmission losses and unaccounted for losses	634,775	
	1,118,961	
Received for all electric energy generated		.03296
Received for all electric energy sold		.04114
Load factor	34.08	per cent.
Capacity factor	21.96	per cent.
Revenue per kilowatt-hour station capacity		$63.40
Maximum demand		1,965 kw.

The street-lighting system operated and maintained under the supervision of the municipal station consists of

over 1,300 ornamental lighting standards in the business and residential districts, both electroliers and single ornamental lamp-posts. These are equipped with a total of about 3,700 lamps, ranging from 25 to 100 watts capacity. About 150 inclosed arc lamps are installed in different sections of the city, together with an aggregate of over 2,000 tungsten lamps of 6.6 amp., varying from 40 to 1,000 cp. in size. Tungsten lamps of 60 and 100 watts are used for alley lights.

During the past year extensive additions and changes have been made to improve the street-lighting system. All arc lamps are soon to be replaced with gas-filled mazda lamps of 600 cp. rating.

The diagram, Fig. 1, shows the continual extension in the street-lighting system and the increase in the candlepower of this part of the service since the establishment of the municipal power station. Diagram, Fig. 2, gives

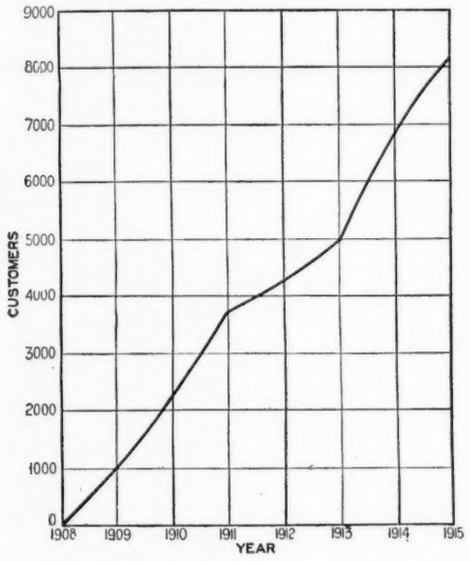


FIG. 2. YEARLY GROWTH OR INCREASE IN CUSTOMERS

an idea of the yearly increase in the number of consumers for the entire period of operation of the station.

The following schedule of rates has been established for various classes of service:

Incandescent Lighting—Schedule is divided into five classes, as follows: Class A—For the first 100 kw.-hr. or less furnished in any one month to any consumer, 5c. per kw.-hr. Class B—All consumption in excess of 100 and not exceeding 500 kw.-hr., 4½c. Class C—All consumption in excess of 500 and not exceeding 1,000 kw.-hr., 4c. Class D—All consumption in excess of 1,000 and not exceeding 2,000 kw.-hr., 3½c. Class E—All over 2,000 kw.-hr. furnished in any one month to any consumer, 3c. per kw.-hr.

Arc Lighting—Schedule is arranged in three classes, as follows: Class A Arc—For the first 100 kw.-hr. or less furnished in any one month to any consumer, 4.9c. per kw.-hr. Class B Arc—For all consumption in excess of 100 and not exceeding 500 kw.-hr., 4½c. Class C Arc—All over 500 kw.-hr. furnished in any one month to any consumer, 4c. per kw.-hr.

Power, Heating, Etc.—The schedule of rates for power, heating or other purposes than lighting is divided into eight classes, with reduced rate for increased consumption in each class, as follows: Class A Power—For the first 100 kw.-hr. or less furnished in any one month to any consumer, 4c. per kw.-hr. Class B Power—In excess of 100 and not exceeding 300 kw.-hr., 2.4c. Class C Power—In excess of 300 and not exceeding 500 kw.-hr., 2.4c. Class D Power—In excess of 500 kw.-hr. and not exceeding 1,000, 2c. Class E Power—In excess of 1,000 and not exceeding 1,500 kw.-hr., 2c. Class F Power—In excess of 1,500 and not exceeding 2,000 kw.-hr., 1.9c. Class G Power—In excess of 2,000 and not exceeding 3,000 kw.-hr., 1.8c. Class H Power—All over 3,000 kw.-hr. furnished in any one month to any consumer, 1.2c. per kw.-hr.

For power service a monthly minimum charge of one dollar per meter of 1½-kw. capacity or less is made, with an extra charge of 75c. for each additional kilowatt of meter capacity required.

The following street-lighting rates for different capacity of lamps are now effective: Arc lamps, 6.6 amp., $60 per annum; tungsten lamps, 80 cp., $12 per annum; 125 cp., $15 per annum; 400 cp., $48 per annum; and 600 cp., $60 per annum; cluster posts, 3 to 4.3c. per kw.-hr.

During the last fiscal year of operation, over $70,000 has been expended for improvements and additions. Of this amount $34,685 has been used for new station equipment including boilers and generators, and $14,790 for the overhead distributing system, embracing poles, crossarms, wire, etc. Other expenditures have been: Real estate and buildings, $2,580; transformers and devices, $4,222; meters, $7,621; municipal street-lighting system, $3,919; general equipment, including telephone lines, $1,730; and underground distributing system, $471.

It is interesting to note that the rate of return on the depreciated value of the property was 9.36 per cent. during this period, as compared with 8.75 per cent. for the previous year. The total interest and depreciation for the period per kilowatt-hour was: Electric energy sold, $0.01177; electric energy generated, $0.00944.

Pointers in Selecting Motors

By A. G. Drury

1. Bearings should be dustproof.

2. The covers of the oil wells should close by gravity, even though springs are used.

3. Oil wells should be supplied with a gage. It is best to oil the bearings through the gage. Oil attacks the insulation of the wires, and if there is too much in the wells, it may be drawn up into the windings of the motor.

4. Bearings should be so designed that the oil ring cannot get out of its slot.

5. Bearings should be put on from the inside of the housing.

6. See that the frame is so designed that the motor may be mounted on the floor, wall or ceiling without great change.

7. See that the bolts have no strain except to hold the frame and housings together. The housings should rest on a little shoulder in the frame.

8. The frame should be so constructed as to give the best ventilation; for instance, a box-type frame may feel cool on the outside while the laminations or core within may be very warm.

9. The frame should be so constructed that the laminations of the core are held tightly together and have no chance to hum. A hum indicates a movement which would soon wear out the insulation.

10. The ends of the coils should be protected in some manner, either by the housings or the frame.

11. The windings should be well insulated from the frame and the phases from each other.

12. The leads should be so fastened and protected that they will not pull out of the motor. In fact, it should be possible to drag the motor around by the leads without pulling them loose.

13. Note the solidity of construction of the coils, which overhang the slots of the rotor or stator.

14. Note the protection afforded by the slots of the rotor or stator to the windings.

15. Note whether the windings are so placed in the slots that there can be no movement of the wires.

16. It is best to have commutators slightly rounded at the outer edge, for an accidental blow on the edge, if sharp, may spread the copper of the bars over the mica between them, causing a short-circuit.

17. There should be plenty of area for good commutation—the proportions liberal rather than cramped or skimped.

18. The commutator should be wide enough so that the brushes can be staggered and not form grooves in the commutator by all wearing on the same part of its surface.

19. After all this inspection, see if the motor as a whole looks good mechanically. An engineer is bound to have developed this instinct to a considerable degree.

Visits of Inspector Brown--XXI

By J. E. Terman

SYNOPSIS—Brown and the Chief have another discussion regarding diagramming formulas. The Chief explains why certain diagrams are made with straight lines.

When the Chief came in from lunch, he told Brown, as he passed the latter's desk, that he might come in as soon as he liked, to continue the discussion of how to diagram formulas. "Well," said the Chief, as Brown seated himself on the opposite side of the table, "when we were talking about this subject last week, we found that the weight of a column of water of any height and the multiplication tables might be readily represented by diagrams using straight lines, but I did not explain why this was so, and so I will attempt to do so now.

"Here is a right-angled triangle *AOB*," producing the sketch shown in Fig. 1. "We will extend the base and the hypotenuse of this triangle and draw another line *CD* perpendicular to the base line. In the study of geometry you learned that the triangles *AOB* and *OCD* are similar, that $\frac{AB}{OB}$ would give the same result as $\frac{CD}{OD}$ and that the base line and the hypotenuse might be extended indefinitely and any number of vertical lines might be drawn parallel with *AB*, and the height of any one of these lines divided by the distance from O to where the vertical line intersects the base line would give just the same value as $\frac{AB}{OB}$ or $\frac{CD}{OD}$.

"Suppose that this constant value of $\frac{AB}{OB}$ is taken as ½, which would be the case if the proportions were the same as in the sketch. We would have $\frac{AB}{OB} = ½$, which we will call formula 1. From the fact that all the vertical lines formed similar triangles, any vertical may be substituted for *AB* in formula 1, provided that the distance from *O* to this vertical is substituted for *OB*, and the formula will be equally true for the new values and the top of each vertical will always be at the intersection with the hypotenuse, extended if necessary, of the original triangle *AOB*, and this hypotenuse is of course a straight line. Now in writing formula 1, we may represent the unknown value of any vertical by y and the distance of such vertical from *O* by x. You will remember that in algebra, x and y are generally used to represent unknown quantities, and in this case they represent unknown quantities that are variable in value. But the value of one is dependent on the value of the other; that is, as soon as a value is assigned to y, the value of x becomes fixed or vice versa. Substituting y and x for *AB* and *OB* in formula 1, it becomes $\frac{y}{x} = ½$, or formula 2. Any other line, such as *OE* or *OF*, might have been used as the hypotenuse of our triangle, but of course in such case the length of the verticals

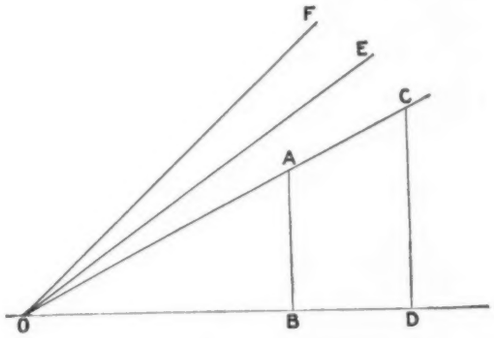


FIG. 1. RIGHT ANGLE TRIANGLE

from the base line to these lines, divided by the distance of the verticals from *O* measured on the base line, would not be equal to ½ as before, so that in formula 2 we will substitute the letter a for the ½, in order that a may represent any ratio between the length of the base and that of the side of a right-angled triangle perpendicular to this base; and as we have seen, with the value of a fixed or constant, as it is called in mathematics, the tops of all the vertical lines will lie on a straight line which is the hypotenuse of the triangle formed. Substituting a for ½ in formula 2, it becomes $\frac{y}{x} = a$ or $y = ax$, which we will call formula 3.

"In representing equations by lines, it is customary to draw two lines at right angles to each other like this," showing the sketch Fig. 2, "these lines representing the base line and the right-hand vertical line in the case of our former diagrams of the pressure exerted by a column of water and the multiplication table. The inter-

section of these lines at O is the same as the point O at the common angle of the right-angled triangles we have been considering here. The vertical line is called the axis of y and the horizontal line the axis of x, and for the sake of simplicity these lines should always be referred to as the axis of y and the axis of x respectively—not because there is any particular significance in the use of these letters, but because they are always used to represent the coordinate axes, and by learning this way you will understand what is meant when you see the axis of x or y referred to in the future. A line is considered as made up of an infinite number of points, and when a line represents an equation, every point of the line must satisfy the requirements of the equation, just as the points at the top end of all the vertical lines on this figure," producing Fig. 2, "satisfy the equation $y = ax$, because if x and y represent the distances of points from the axis of y and x respectively, the position of such points would be the same as G, H or I and we have found that these points would lie on a straight line. Since this is known to be a straight line, it is only necessary to obtain two points on it in order to draw it, and by giving a value of 2 to a and assuming a value of 2 for x, then the value of y would be $y = 2 \times 2$ or $y = 4$ and the position of this point would be shown at K, in this sketch" (shown in Fig. 3). "Now for this particular equation, Brown, the zero point would be another point on this line, for as may be readily seen from the formula $y = ax$, if x is given a value of zero, then y must also have a value of zero, and the intersection of the axis of y and the axis of x is the only point that can fulfill these requirements. Therefore, by drawing a line through K and O, this line will represent the equation $y = ax$, when $a = 2$."

"Chief, I believe that I can see why $y = ax$ would be a straight line, but how did you know that the multiplication table could be represented by a straight line," asked Brown.

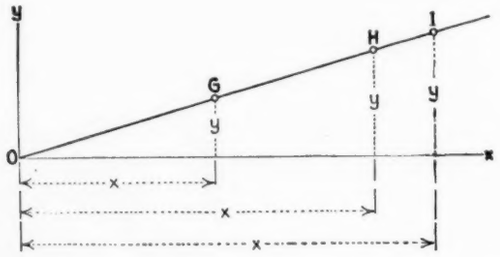


FIG. 2. BASE AND VERTICAL LINE CONSTRUCTION

"You don't mean that, Brown, for if you will remember, the multiplication table was represented by twelve straight lines, one for each separate table, and it is easy to see how this could be by writing a formula for the multiplication table. You know that the multiplicand times the multiplier gives the product, or denoting the multiplicand by x, the multiplier by a and the product by y, the formula for the multiplication table would be $ax = y$, which you will see is a straight line passing through the intersection of the axes of x and y. That is, when any particular multiplier is used, as denoted by a in the formula, the particular table of the multiplication table for that multiplier may be represented by a straight line, and the complete table may be represented by twelve lines, all passing through the intersection of the axes of x and y. In the case of the multiplication table, it would have made no difference whether the constant a was used to represent the multiplier or the multiplicand, and you will remember, Brown, that these two factors in the diagram we drew could have been interchanged at will without affecting its usefulness.

"In the case of the diagram used to give the pressure exerted by a column of water of any height, you will remember that the constant value was the weight of a column of water a foot high, or 0.434 lb. per sq.in., and the variable quantities were the height of the column in feet and the pressure exerted by the column due to the weight of the water in pounds per square inch; and representing the pressures by y and the height of the column by x, the formula for the line in that diagram would be $y = 0.434x$, and you can see that if y should have a value of zero, x would also be zero, so that the line would pass through the intersection of the axes of x and y."

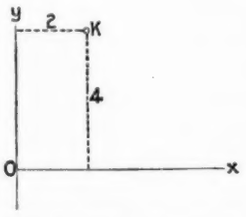


FIG. 3. DETERMINING THE POINTS K

"Chief," said Brown, "do all straight lines representing formulas pass through the intersection of the axes of x and y?"

"No. Brown, but it is too late to continue the subject this afternoon. If you will come in tomorrow, we will try and discuss some straight-line formulas that would not pass through the section of the x and y axes."

JUST FOR FUN

Mechanical Information (?) via the Daily Press

The following is an "honest-truly" attempt of the daily newspaper "cub" to write up a flywheel explosion, particulars of which appeared in our issue of Oct. 31:

Six hundred and fifty men who reported for work Thursday found the mill had been shut down because of an explosion of a steam engine. According to men who worked at the plant Wednesday night, the explosion occurred when too much steam was allowed to form in a boiler. The steam engine, which operates two large dynamos, began to speed up, in turn speeding up the dynamos. The dynamos revolved so fast that parts became loosened and the boiler on the engine exploded. A large piece of steel was blown through a brick wall and then through the roof. Men noticed the electric lights brighten when the dynamos began to speed and fled. A piece of a 10-foot flywheel was found a quarter of a mile away near a bridge.

We bespeak his protection on the same score as the woolly Western dance hall "pianist": "Don't shoot; he is doing the best he can."

⌘

Automatic Cutoff Engines regulate their speed by cutting off the steam supply according to the load, thus using a greater degree of expansion than when, as in the throttling engine, the cutoff is late enough to carry the maximum load. The slide-valve throttling engine regulates its speed by throttling the steam between the boiler and the cylinder.

⌘

Copper Substituted for Aluminum—Owing to the great demand for aluminum for the manufacture of munitions, the Ontario Hydro-Electric Commission has substituted copper for aluminum wire on its main transmission lines and by so doing has recovered over 80,000 lb. of aluminum for munition making. Aluminum has been largely used in a number of the smaller low-tension lines in connection with this system, but it is expected that before long the entire system will be entirely equipped with a copper transmission service.

Internal-Combustion Turbine

By A. W. H. Griepe

SYNOPSIS—The construction and operation of a 100-hp. internal-combustion turbine which has made a number of runs is described.

At the present time a great deal of attention is being paid by inventors and experimenters to solving the problem of the internal-combustion turbine. The machine here described is rated at 100 hp. and has made a number of runs. The results so far obtained are promising, an efficiency of about 20 per cent. having been indicated by a rough test.

The turbine consists of a rotor similar to that used in a reaction-type turbine, with the blades distributed in four equally spaced groups around the periphery of the wheel. Each group occupies one-eighth of the circumference, as shown in Fig. 4 and in the cross-sectional views, Figs. 1 to 3. On the rotor is mounted a valve band *R*, also shown. The band acts as an admission and cutoff valve between the explosion chamber and the fuel and air supply. The stationary element contains the explosion chamber, also the ring chamber for the fuel and air supply, as shown in Figs. 1 and 3. It will be seen that the nozzles are mounted so that the gases flow from the inner to the outer periphery of the wheel.

The operation of the turbine is best explained by referring to Figs. 1 and 3. Compressed air enters the air chamber from the storage tank at from 45 to 75 lb., and the gas from the fuel chamber at approximately atmospheric pressure. In Fig. 1 the wheel is in a position where the nozzles leading from the explosion chamber to the blades are closed and the ring *R* has opened the admission from the fuel and air supply to the explosion chamber. The compressed air flows in through the passages indicated by the curved arrows. In doing so it acts as an injector and draws the fuel in through the small straight nozzle in the center of each valve, as indicated by the straight arrow. This continues until the wheel has revolved to the position shown in Fig. 3. Here it will be seen that the ring *R* has closed the passage between the fuel and air supply and the explosion chamber and that the port is open between the explosion chamber and turbine blades. The valve ring closes the port between the fuel and explosion chamber an instant before the port is opened from the explosion chamber to the blades, and at this instant the charge is ignited and expands from the position of the wheel in Fig. 3 to that in Fig. 1. The ring *R* opens one side of the air valve before the gas valve opens, and the nozzle from the explosion chamber to the turbine wheel does not close until the gas valve is opened; this allows a charge of air to be blown through the explosion chamber, which scavenges it and prevents backfiring.

The turbine is in duplicate, with the nozzles on one side placed in angular position by one-eighth of a revolution from those on the other side, so that when one side is in expansion the other is taking in a charge in the explosion chamber. This gives approximately a constant turning effort on the turbine wheel.

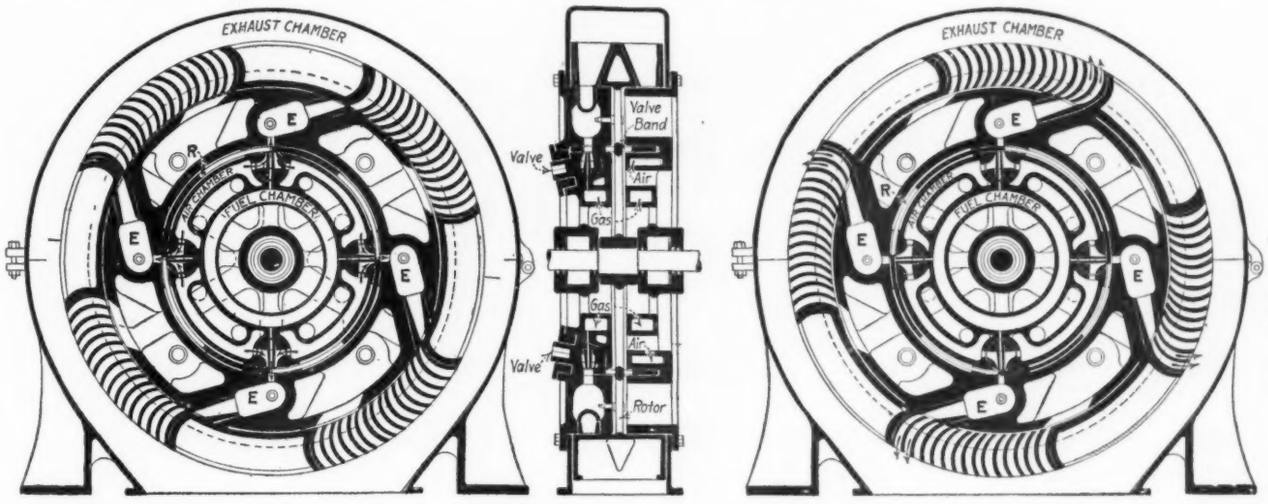


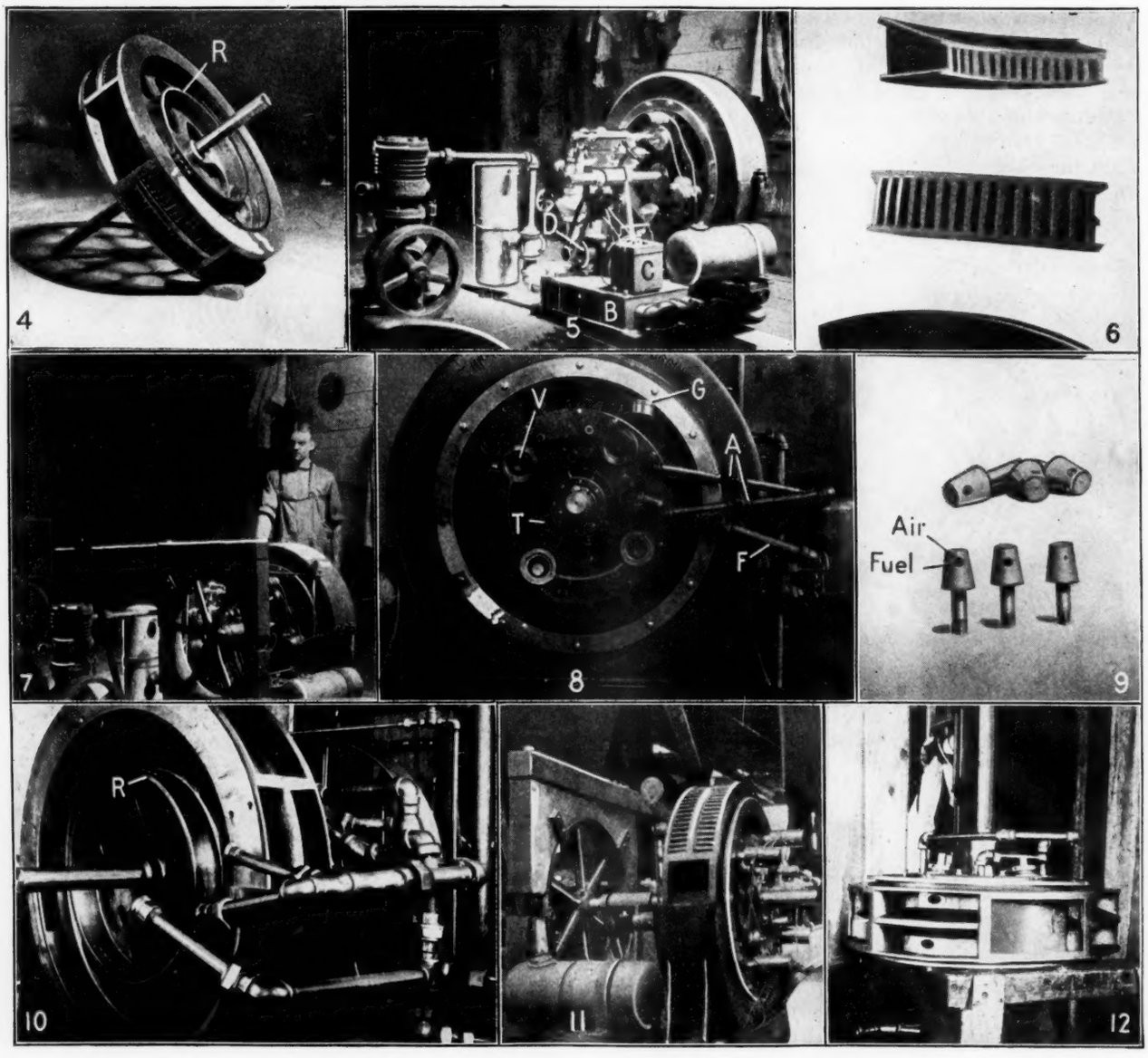
Fig. 1 Fig. 2 Fig. 3

FIG. 1. POSITION OF TURBINE WHEEL AT BEGINNING OF ADMISSION. FIG. 2. LONGITUDINAL CROSS SECTION OF TURBINE. FIG. 3. POSITION OF TURBINE WHEEL AT BEGINNING OF EXPANSION

The operation of the turbine may be explained from the cycle diagram in Fig. 13, as follows: Starting at I, expansion is complete and the ring valve is just beginning to open the air valve, with the explosion chamber still open to atmosphere. Air is admitted to the explosion chamber, blows out through the exhaust and scavenges the explosion chamber. This continues for 10 deg. of the revolution, as indicated, at which point the nozzle from the explosion chamber is closed by the inner rim of the rotor. At point II the valve band *R* opens the fuel valve, admitting a fresh mixture into the explosion chamber, and the pressure rises, owing to the pressure of the compressed air. At III, 40 deg., the valve band closes the admission opening. When the valve band has overlapped 1 deg. at IV, 41 to 42 deg., ignition takes place. At this point the highest pressure is obtained, V. From 42 to 45 deg. the nozzle is opening from the explosion chamber and expansion begins. From 45 deg., VI, to 90 deg. the nozzle is wide open and expansion takes place. At 90 deg. the cycle is complete and begins over again.

Fig. 5 shows the complete unit with air compressor. As no complete data were available for the quantity of compressed air necessary except the data obtained by Holzwarth, Stolze, etc., the necessary amount of air had to be determined by experiment. The first installation, Fig. 5, was a 3x4-in. Gardner compressor. The amount of air delivered was large enough for two explosion chambers, one on each side, the least number of chambers the turbine can be throttled down to. The air leakage between the nozzle closed were 48, 57 and 70 lb. gage respectively. The power necessary to compress the air was about 15 per cent. of the whole power developed, which later was improved to 12 per cent.

The combustion, it is claimed, never gave any trouble. When starting, the pressure on the fuel was about 3 lb., but after a short run the mixing valve acted as an injector and forced the fuel into the explosion chamber by suction, thus making a carburetor unnecessary.



FIGS. 4 TO 12. DIFFERENT PARTS AND ASSEMBLY OF GAS TURBINE

tank and the explosion chamber was at that stage about 25 per cent. This loss proved to be too large, and adjustable nozzles were installed, as shown in Figs. 1 and 3. This reduced the losses to about 10 per cent.

A 6x6-in. double-cylinder Curtis compressor was installed, and proved sufficiently large to run the turbine, producing 85 to 90 hp. at 2,500 r.p.m. The loss of air leakage was still 9 per cent. A floating valve was next installed near the valve-band opening in the explosion chamber (not shown), and the leakage or loss was reduced to the following figures: With tank pressures of 50, 60 and 75 lb., the pressures in the explosion chamber with

The heating coil in the exhaust base *B*, Fig. 5, heats the fuel to a high temperature, thus assisting in vaporization. The turbine has been operated with two, four, six and eight explosion chambers in action. By turning the mixing valve 45 deg. and switching the spark-plug coils out, the relative explosion chambers become active or inactive, thus saving fuel and current when the full output of the turbine is not needed.

Fig. 6 shows the vane-blade sections, which are made of cast iron and inserted in the rotor. They have stood the various trial runs well. The sections are cast in one piece and can easily be replaced by simply lifting the ex-

haust hood without disturbing the whole unit. The thickness of the blades ranges from ⅛ in. near the edge to ¼ in. in the middle. Fringing occurred only on places where the core left a very thin edge, due to irregularity in the loam core.

Fig. 7 shows the comparative size of the turbine complete and Fig. 8 an end view showing the air pipes *A*, a fuel pipe *F*, the valve seats *V*, the timer *T* and the

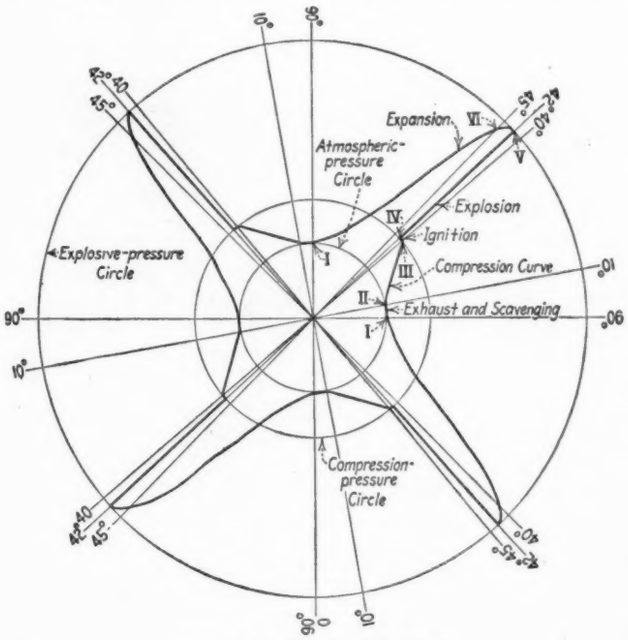


FIG. 13. CYCLE DIAGRAM

pressure gage *G*. In Fig. 10 the explosion-chamber section is removed to show the details of the rotor and housing. The top part of the turbine casing is removed to show the rotor in Fig. 11. Fig. 9 shows the valves; the

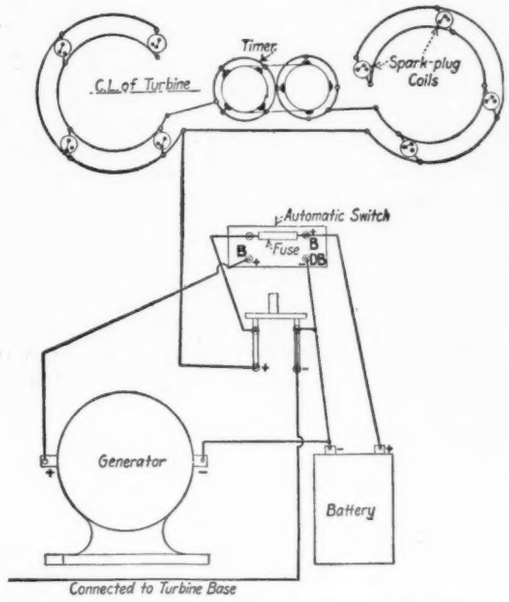


FIG. 14. WIRING DIAGRAM OF THE IGNITION SYSTEM

fuel and air passages are indicated on the figure. The rotor of the turbine with the blade sections removed is shown in Fig. 12.

The electrical equipment—the ignition system, the part of the turbine that apparently would seem the easiest of all—nearly proved a stumbling block. Several experts recommended schemes that took up considerable space, but none of them proved successful. However, the inventor of the turbine by using spark-plug coils, four on each side, successfully solved the difficulty. This did away with the lag in the current and has proved entirely satisfactory. Two of the spark coils are shown mounted directly on the plugs in Fig. 5. Current is supplied from the battery *C* while starting. After the turbine comes up to speed an automatic switch throws the sparking system over on the generator *D* and the battery on charge.

The wiring for the sparking system is shown in Fig. 14. The current produced by the generator is conducted through the automatic switch, where one circuit goes through the battery and keeps it charged while a second circuit leads to the spark-plug coils and the timer. The timer is made up of eight contact points, each representing an explosion chamber. The points are alternately connected, four for either side. A separate circuit from each of the rings leads to the plug coils, so it will be seen that the rollers make the contacts for four coils simultaneously. This arrangement proved successful even up to a speed of 3,500 r.p.m.

Bakelite Micarta-D Gears

A nonmetallic gear material successfully meeting high-speed requirements has been placed on the market by the Westinghouse Electric and Manufacturing Co., of East

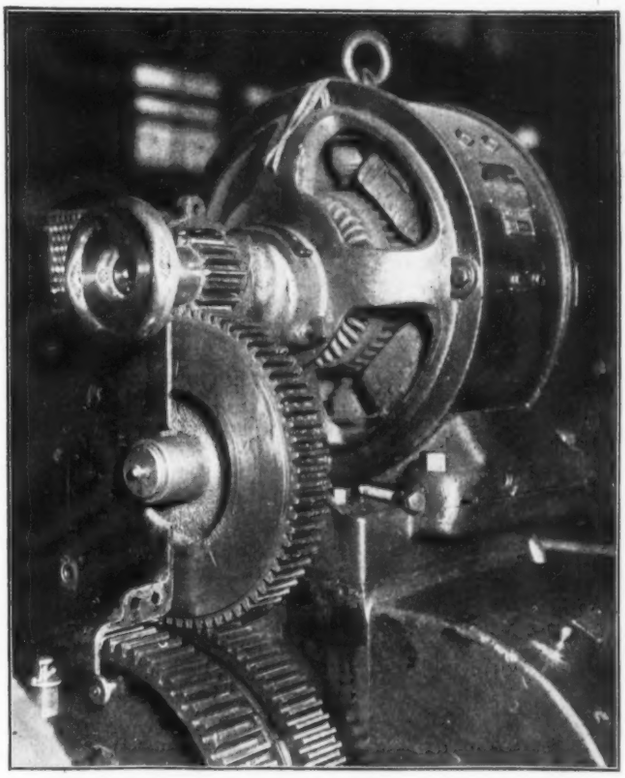


FIG. 1. SHOWING AN INTERMEDIATE GEAR WITH END PLATE

Pittsburgh, Penn., under the name of Bakelite Micarta-D. This is a product of heavy duck bonded together with Bakelite by heating while under heavy pressure. It is as strong as cast iron, is unaffected by atmospheric changes, is vermin-proof, and can be stored indefinitely without

shrinking or other deterioration. It can be used for gears that have to operate in oil, without any signs of swelling. In most cases neither bushings nor shrouds are required, as the material is self-supporting. Where, however, the requirements are unusually severe or where the diameter of the gear is several times the width of the face, end plates may be used, but even in such cases the teeth need not be shrouded and the width of the gear is determined only by the power to be transmitted. Generally the width of the face of these gears is made the same or

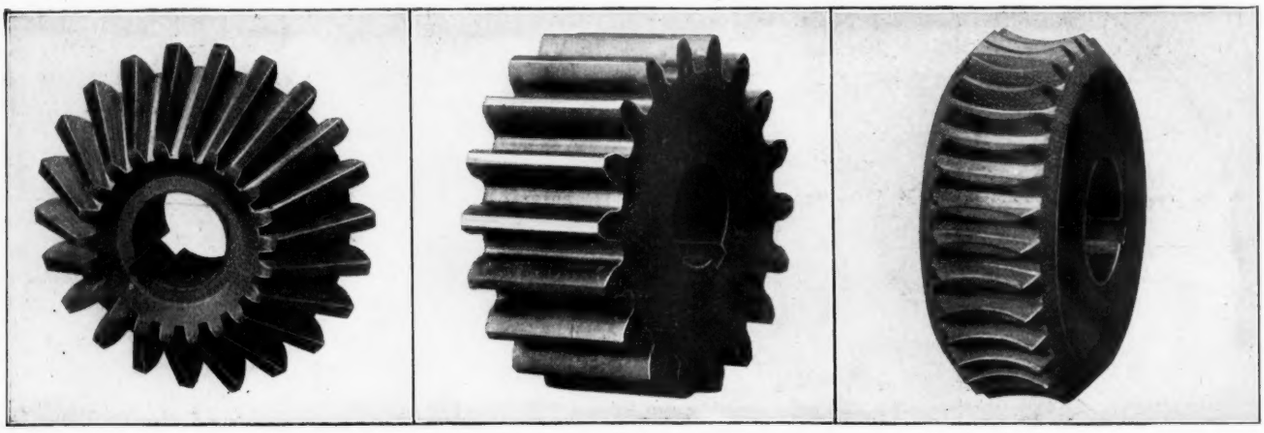


FIG. 2. SHOWING A PLAIN SPUR AND TWO FORMS OF SPECIAL GEARS

less than the mating gears in order to insure uniform pressure over the entire teeth.

The material of which the gears are made has a tensile strength parallel to the laminations of 10,000 lb. per sq.in.; a compression strength of 30,000 lb. per sq.in. perpendicular to the laminations, and of 17,000 lb. per sq.in. parallel to the laminations; a transverse strength of 17,000; a coefficient of expansion per inch per degree Centigrade, of 0.00002 in. in the direction parallel to the laminations and of 0.000085 in. in the direction perpendicular to the laminations. It has a specific gravity of 1.4, weighs 0.05 lb. per cu.in. and has a water absorption of 0.25 to 2 per cent. by weight, depending upon the relative amount of edge surface exposed. Shrinkage and oil absorption is practically zero. Three types of gears are shown in Fig. 2. Fig. 1 shows an intermediate gear with end plates.

Famous Yadkin Development Nearing Completion

Back in 1913 and 1914 there was considerable discussion about the sixteen 5,200-kw. direct-current generators that were to be installed in the plant of the Southern Aluminium Co., Whitney, N. C., at the narrows of the Yadkin River. According to *Engineering News* this work was halted when the European War broke out, as this company was a French concern. After about a year's interim this industrial site was purchased by the Tallassee Power Co., a subsidiary of the Aluminum Company of America. Under the new owners was built a solid concrete dam about 1,400 ft. long, 217 ft. maximum height and containing 525,000 cu.yd. of concrete, making it the highest overfall-type dam on record.

The plans of the French company to install direct-current machines were abandoned. A new power house was built across the river from the site of the direct-current plant. This is designed to house four 27,000-hp. single-runner vertical-shaft Francis turbines, driving alternating-current generators. These are, by a considerable margin, the largest single-runner turbines yet built. Only three units are to be installed at the present time. The turbine runners are 108 in. diameter, running at a speed of 154 r.p.m., working under a 165- to 180-ft. head.

One feature of particular interest is the method adopted for removing the turbine runner without disturbing its generator or dismantling much of the turbine itself. The upper section of the draft tube telescopes downward, exposing the runner, which can be lowered on a spider carried by a cable running up through the hollow turbine and generator shaft to the main station crane hook. The runner, once clear of the shaft, is lowered upon a service car and shoved out through an adit.

The turbine runner weighs 20,000 lb., is a single piece of solid bronze and is probably the largest casting of the kind ever made. The total weight of the revolving parts is 144,000 lb.; this weight and the reaction thrust of the loaded runner are carried by a Kingsbury thrust bearing.

Each turbine drives a 18,000-kv.-a. 36-cycle 13,200-volt three-phase generator with a 72-kw. 250-volt direct-connected exciter. They have an overload guarantee of 22,500 kw. at unity power factor. The efficiency at 18,000 kw. and unity power factor is said to be 96.6 per cent.

As the head available for the operation of these units will vary considerably, two guarantees of output at given heads are made. Each unit is designed to deliver to the generator shaft not less than 27,000 hp. when operating under an effective head of 165 ft. and running at a speed of 154 r.p.m. Under these conditions it is to develop an efficiency of not less than 90.5 per cent. (efficiency being defined as ratio of water horsepower delivered to the unit to mechanical horsepower at the turbine shaft). Each unit is also guaranteed to deliver not less than 31,000 hp. operating under an effective head of 180 ft. and at 154 r.p.m.

A 36-in. diameter model runner was constructed and tested at Holyoke, Mass., having dimensions homologous to those of the large designs. An efficiency of practically 91 per cent. was shown, and it is expected that this will be exceeded in the large units by a considerable margin.

Editorials

Safety-First Starting Apparatus for Electric Motors

The general safety-first campaign has produced a number of new devices for the better protection of operators when starting and controlling electric motors. In order to fully appreciate their advantages and the reasons for their development, it is first necessary to understand the basis of the whole safety-first movement.

In the "dark ages" of industry, before the safety-first slogan had been heard, accidents were accepted as normal occurrences. It was a case of "let the workman beware," and if he did not, the consequences were on his own head. But now the tide has turned. The progressive manufacturers have come to realize that a trained employee is an asset and that if he is disabled, there is a real loss until he is replaced by another man of equal training and efficiency. There is a realization that the training of an employee is an investment and that the principal invested is lost if he is killed. So these manufacturers began the work of removing the hazards of labor. They started the safety-first movement.

Once started, the campaign gained momentum very rapidly. The humanitarian employers were quick to take it up. The workmen, finding themselves better protected in some places than in others, began to make their voice heard in legislative chambers. This resulted in city and state laws requiring that hazards be removed and that operators be better protected from dangerous machinery. Factory inspectors were appointed to see that the laws were enforced. Finally came the workmen's compensation laws. These brought into line employers who previously had been unable to see any advantage in protecting their men.

Now safety-first devices are considered as much of a necessity as fire insurance. In reality they are worth more than any insurance, for if the device affords real protection to the workman, it does more than insure against the possibility of accident—it eliminates the possibility. Moreover, incidental advantages have accrued wherever safety-first devices have been installed. Chief among these is the greater efficiency of the operator, due to relief from mental strain.

While great strides had been made in the design of new machines to make them safer for operators and while laws had become very stringent regarding the protection of workmen from moving belts, gears, shafts, etc., until two or three years ago comparatively little had been done along safety-first lines in the design of starting apparatus for electric motors. Old starters were built like old switchboards—mainly a piece of slate with a great number of "live" parts on the front—but while power-station boards were operated by men having some electrical knowledge, the miniature switchboards for starting motors were put into the hands of the ordinary machine operator.

Now, however, exposed current-carrying parts on switchboards are no longer considered good practice. In the larger power stations one finds remote-control benchboards from which all the operating is done, and in other classes of stations the best practice calls for steel panels of the removable truck type with everything on the front of the panel "dead." If protection from live parts is needed in the power station, where the attendants are so familiar with electric devices, how much more important it is that the man at the machine, who has his mind on other things than electricity, be afforded protection. This necessity has not been overlooked by the electrical manufacturers and engineers, and now there is a safey-first electrical equipment available from a small push-button to the largest controllers. Elsewhere in this issue is published an article on "Safety-First Starting Apparatus for Electric Motors." This presentation is representative of the tendency in the electrical industry today, consequently it is befitting that it be published at this time, "The Electrical Week."

Discussion in Power

On another page of this issue a contributor in defending statements made by him in former issues says: "When I wrote my article entitled 'The Value of Cylinder Oils,' which was published in the issue of *Power* of April 11 last, I naturally supposed the readers would take into consideration that the article was addressed to that particular class of readers for the benefit of whom *Power* is published—the superintendents and operating engineers of power plants."

This statement by Mr. Carpenter, who for many years has been a reader of and a contributor to *Power*, warrants a word of advice to others who may discuss engineering in our columns. It is true, of course, that most of our readers are operating engineers and mill or factory superintendents and managers; but one must remember that among our many thousand readers and contributors there are hundreds of consulting engineers, many chemists, scores of professors of mechanical and electrical engineering, besides designers and builders of power-plant equipment, and others.

The present discussion of viscosity in cylinder oils as introduced by Mr. Carpenter began at a time when more interest was centered on the subject of oils and lubrication than had been given to them in years. Naturally many persons are keenly interested in the discussion. Viscosity is a physical property of an oil. Those most familiar with it are the chemist and the engineer with an understanding of the chemistry of oils and with their behavior under working conditions. Who is more likely, who is more competent, to discuss the value of viscosity and the other properties of lubricating oils than such men?

When one introduces an attention-deserving subject for discussion in *Power*, he must expect that it will receive active attention from many different angles by men engaged in many different channels related to the subject in hand, depending upon the nature of the subject. This discussion needs more of the scientific and less of mere opinion than we have had.

Tests of Welded Vessels Made of Boiler Tubes

There appears in this issue an article on autogenous welding as applied to pressure vessels made by inclosing, with variously formed and welded heads, the ends of boiler tubes, the vessels being subjected to eight hundred pounds steam pressure with one hundred degrees superheat, and later to hydraulic pressure until rupture of the specimens occurred. In no case did rupture occur at the steam pressure applied, and in comparatively few cases did the welds rupture or tear. With nearly all specimens fracture began in the unwelded parts before extending, when they did extend, into the welds.

These tests, while very interesting, especially because of the trend toward higher boiler pressures, do little more than confirm what is quite generally known; namely, that autogenous welding may be made safely applicable for very high pressures to such small diameters as boiler tubes in common use. The conditions are radically different in large vessels like boiler shells, coolers and receivers for refrigeration work, etc. With the small tubes, most of the metal becomes hot enough for the stresses to flow as they arise, and when this happens it is not likely that serious stresses exist and localized fatigue is negligible—a most important advantage for the weld.

Overlapping Construction Costs

In the segregation of power-plant construction costs, where work is installed piecemeal, care is necessary in establishing both total and unit figures. In a large station, for instance, that is being extended from time to time to meet the demands of increasing load, one part may be completed to a greater proportion of the ultimate than another. Coal chutes and ash hoppers may be installed for more units than go into the building at a particular time; piping may be installed on a more extended plan than the addition of a single unit or two would require, in order to save on the final installation cost or to secure additional flexibility at the earlier stage of the work; floor construction, galleries, bus structures and many other details may all be pushed to fuller completion than the prime-mover conditions may indicate or require. The natural result is that in many cases incorrect or at least incomplete segregations are made; and if these segregations get into public use, as they may in plants under the general supervision of commissions or other governmental bodies, incorrect conclusions may get abroad.

The only way in which such conditions can be satisfactorily met is by maintaining a complete and accurate record of the progress of the installation, supplemented by such detailed costs as can be deduced from the outlay required by individual items.

Even if it proves to be the case in a given station that the total cost of installing turbine No. 3 is complicated with the labor and supervisory expenses incurred in the construction of piping and certain auxiliary pumps, etc., that will be required in larger scope when No. 4 and No. 5 go into service, a fair degree of segregation can be realized if the effort is made to do it at the right time. The cost of each important piece of apparatus can be ascertained at least approximately, including its transportation to the plant, and at least a rough estimate can be made as to the cost of its erection independently of other equipment.

The operating engineer in charge should have access to detailed installation costs as well as his superior executive, if the former is ever likely to be called upon to furnish data as to segregated construction expense. In fact, installation costs should be at the operating man's disposal anyway, for where can he secure better data for future estimates affecting the development or reconstruction of his installation? The time has long gone by when a progressive management can justify hoarding away investment cost data in his private safe while he holds his engineer responsible day by day and week by week for the showing a given assortment of equipment makes in service.

The High Cost of Coal

Coal prices have been rising steadily of late, and it is a question how much higher they will go or whether they will ever come down to the normal figures of the past. The phenomenal increase has a number of causes, chief of which are low supply and high demand. The supply is limited owing to the extreme demand by industries working at top speed and the usual great demand at this time of the year for domestic coal. The supply is also limited because, on account of a shortage of railroad cars, many mines have not been able to operate at full capacity. Coal cars loaded with miscellaneous freight for foreign shipment are lying in seaport freight yards awaiting merchant freight steamers to be unloaded, and the inadequate number of these steamers available prolongs the delay.

The continuously increasing seriousness of the labor conditions, high wages and throttled mine output, and the almost helplessness on the part of the coal operator to protect himself from this side, is another serious cause. The labor question, in fact, is becoming so grave that within the next five or ten years the cost of coal may double without considering the present increase. The only thing that will prevent this is regulation on the part of the Government, on the order of public-service commissions—regulation not only of the operators, but also of the miners and the insistence that this communal necessity be sold on a basis of cost plus a fair profit.

The cost of coal will drop again when the demand for domestic use decreases and also after new mines open up, as always happens when good money is received for the coal mined. It is improbable, however, that prices will ever drop to the figures common before the present rise.

While economy in the power plant has always been important, it will have more weight in the future. The effort to operate the plant economically should be in direct proportion to the price paid for coal. When the cost of coal doubles, the effort to save as much of it as possible should also double.

While the supply of coal is not inexhaustible, it will last a long time, but its cost on the market will increase, and this to a good manager will be fully equal in importance to a decrease of supply. Competent engineers will be in greater demand, and it will be of increasing importance, sooner or later leading to his financial benefit, that every engineer become thoroughly posted upon economical power plant operation.

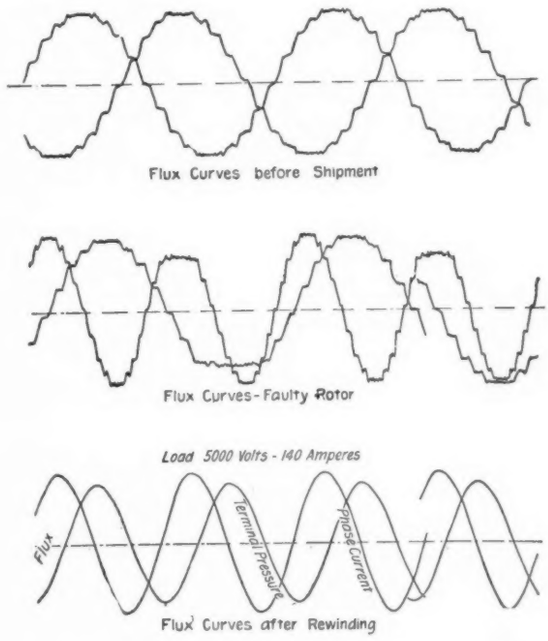
Correspondence

Vibration in Steam Turbines

As outlined by H. A. Fisher in the issue of Oct. 3, page 489, there are various conditions that either singly or in combination may cause vibration in a turbine and alternator set, and I should like to add another, which may lead to considerable trouble and expense, as is shown in the following case.

Four turbo-alternators had been installed—two of the mixed-pressure type situated at one end of an overhead transmission line and two of the high-pressure type at the other end of the line, each having an output of 1,700 kw. three-phase alternating current at a power factor of 0.75, 5,500 volts, 50 cycles, at 1,500 r.p.m. After running the first of the mixed-pressure sets for several days under normal load conditions (coal mines), it started to vibrate so badly that it had to be shut down.

It should be mentioned that the turbines had been manufactured by one firm and the generators by another



OSCILLOGRAPH RECORDS FROM ALTERNATOR

and that the combined sets had not been tested at the works, although each had been separately tested before shipment.

As is usual under such conditions, each maker disavowed the blame, claiming that his machine was all right. Finally they agreed between themselves that the foundations put in by the purchasers were the cause of the trouble. Although the foundations were of a somewhat unusual design—one side of each set resting on a compound girder construction without support in the middle, extending across the width of the engine house—and for this reason might have magnified any vibration, this was not the case, as was later proved. So the makers went through with tests for all other probable causes, one by one, as outlined by Mr. Fisher, examining the balance of the rotating parts, clearances, air-gaps, thrust bearings, etc. The generator manufacturers expressed doubt regarding the flexible coupling. This was promptly replaced by one of another type and finally by a solid one, but the vibration continued. The load was taken off and the set run light, but with no improvement when excited, although when unexcited the vibration ceased.

In the meantime one of the high-pressure sets, with a foundation of a different design, had been put in operation, running for several weeks without vibration. The alternators were then interchanged and other changes made, but without beneficial results on the first set.

Oscillograph records taken before shipment showed nothing abnormal. A new set of records was taken, and as will be seen from the curves, the flux of one of the poles had collapsed. It was found that the insulation of the rotor had become damaged and short-circuited. After rewinding each of the four rotors, the sets ran without vibration.

C. FISCHER.

Brookline, Pittsburgh, Penn.

*

Viscosity in Cylinder Oils

When I wrote my letter entitled "The Value of Cylinder Oils," published in *Power* of Apr. 11 last, I naturally supposed that the readers would take into consideration that the article was addressed to that particular class of readers for the benefit of whom *Power* is published—the superintendents or operating engineers of power plants. [See editorial, "Discussion in *Power*," page 789.—Editor.] I did not suppose the impression would be entertained by any reader that my remarks were intended for the benefit of the oil-trade chemist or for members of any other profession or calling than those who actually use cylinder oils.

["Viscosity is the great humbug test featured in all specifications, and I shall be delighted to debate in *Power* for the benefit of science, the advantages or disadvantages of a viscosity test as applied to cylinder oils." From letter by Mr. Carpenter, in *Power*, Apr. 11, 1916, p. 520.—Editor.]

I said, pertaining to viscosity: "It means absolutely nothing and proves nothing to the *consumer* so far as the final quality of the cylinder oil is concerned." I did not say that my own company did not use the viscosity test in its own laboratories to check uniformity. I did not say that viscosity had no value at all. The meaning I intended to convey, and which I reiterate, is that the viscosity test, as featured by the oil seller, is a humbug.

It is a humbug because, as so featured, the oil seller endeavors to convey to the oil user the impression that his particular cylinder oil is of exceptionally good quality because of its high viscosity test. Such a statement concerning viscosity is deceiving, it is untrue, it is unfair, and it is not borne out by the facts.

The object of inviting debate was not to enlighten the oil trade, was not to bring knowledge to the labora-

tory, but to have an intelligent discussion of this subject, that the man who actually uses the oil might get the benefit of every side of the question. The object was that he might, in the final analysis, decide according to his own best judgment.

When I said that certain tests were difficult to make, I did not mean that they were difficult for the laboratory chemist. My experience in the constant employment of twelve of these professional gentlemen over a period of many years, as well as my experience with the chemists in public consulting laboratories and in the laboratories of other oil manufacturers, has long ago brought me to the conclusion that nothing is too difficult, or impossible, for them to perform—theoretically, of course.

The viscosity test is made by measuring the length of time (in seconds) it requires for a specific amount of oil to flow through an aperture of given dimensions, at a given temperature. It is the measure of fluidity—nothing more, nothing less—and is foreign to the property of viscosity, or "stickiness," as viscosity is defined in the dictionary. It is purely a measure of comparative fluidity.

The man who denies that it is the general practice of oil concerns selling oil to the consumer to argue that high viscosity in a cylinder oil is an indication of high lubricating power is unfamiliar with the consuming oil trade.

But because this discussion is for the benefit of the operating engineer, who has neither the facilities nor the inclination and who would not find it economical to subject his cylinder oils to the usual laboratory tests, I have purposely confined myself in the columns of *Power* to the use of the plainest possible language.

What we oil men do ourselves within our own works or laboratories does not interest the operating engineer. What he wants to know is how he can obtain the best cylinder oil for his specific use. Therefore, in spite of the arguments of chemists to the contrary, the average oil salesman does state to the engineer: "My oil will be the best for your purposes because it has the highest viscosity." This statement is a humbug.

My learned friend, Mr. Jaeger, in the Oct. 31 issue, says: "In some instances viscosity indicates superior quality; in others, inferior quality." In a nutshell, that is all I have ever said or claimed, and if he admits that, he admits my entire argument, as has practically every other critic.

Mr. Jaeger states further, referring to methods of test: "Condemning present methods of test without offering improvements or new methods does not benefit science."

With that statement I take exception. Were it not for the practical man (the practical engineer, for instance) showing up the fallacies of scientific theories, laboratory science would have made little or no advance. No scientific theory has ever become an accepted and proven fact until it has withstood the criticism of the practical man. The laboratory is the place where the maximum of mistakes are made in any manufacturing establishment, and the engine room is the place where the minimum of mistakes occur. In the laboratory errors are not expensive; in the engine room they are both expensive and dangerous, and sometimes fatal.

That it is possible to give to a cylinder oil viscosity by what is known as the artificial method has been practically acknowledged by all critics, but they say that such a viscosity is not necessarily indicative of quality. Why, pray? No critic has yet shown why. If viscosity is not viscosity, what else can it be? What difference does it make how you get it? If viscosity has merit, what difference does it make whether the viscosity is obtained in the still or by a process of blending, so far as the test is concerned? Admitting the claim that such artificial viscosity can be readily determined in the laboratory, it is well to remember that the average engine room does not have laboratory facilities.

Fully 75 per cent. of cylinder oil consumed is consumed by a class of engineers having no access to laboratory facilities. Not 1 per cent. of the laboratories available to the operating engineer of the plant are competent to discover artificial viscosity.

I leave it to the readers to judge whether the admitted fact that high viscosity can be artificially obtained, plus the further fact that such artificial viscosity is generally admitted to be worthless, is not an additional proof of my charge of humbug.

One of the largest and most successful manufacturers in the world said to me: "Where the cost of ascertaining the best quality of any material used in our plant is more than can be saved by using the best, then it is clearly not economical to obtain the best."

In my article I aimed at the practical, hard-headed, common-sense operating engineer—and I seem to have struck the professional chemist.

The lubrication of the interior of internal-combustion engines is almost identical with that of steam engines, the sole difference being that with the internal-combustion engine we have a much higher temperature and carbon gases present, while with the steam engine we have water in gaseous form and moisture condensed upon the lubricated surfaces.

One of my critics has well said that "lubrication is lubrication, whether it is on a bearing or in a cylinder." Why, therefore, if high viscosity is an essential property in the lubrication of a steam engine, is it not equally essential in the lubrication of an internal-combustion engine? We all know that the problem of the lubrication of internal-combustion engines was not solved until the false theory of using oils or high viscosity test was abandoned in this class of work.

I thoroughly convinced myself years ago that at 500 deg. F. every possible steam-cylinder lubricant would show practically the same viscosity, no matter how great the variations were at 212 deg. F. This has been confirmed in several of the articles, it having been admitted by the writers thereof that, as higher temperatures were approached, viscosities became nearer and nearer the same. The significance of this will appeal to the practical engineer. He is as competent to theorize upon it as the best chemist who ever supervised a laboratory.

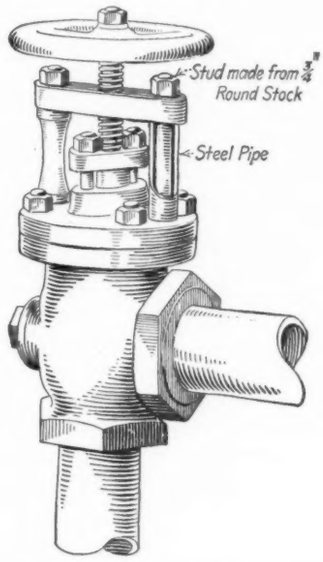
High authorities have been quoted to prove that no one ever claimed that viscosity in itself was an indication of lubricating properties. That is the kernel of my contention.

If those taking up valuable space in *Power* will remember, when writing their criticisms, that this discussion is for the benefit of the practical engineer, the reader of *Power*, I feel that my object in starting the discussion for the enlightenment of the actual oil user will be best accomplished.

CHARLES E. CARPENTER,
President, E. F. Houghton & Co.
Philadelphia, Penn.

Valve Yoke Stud Repair

While making repairs to a blowoff valve, it was found that one of the yoke studs had corroded away to less than half its original size, owing to a leak from the stuffing-box dripping on it. Not having a lathe to turn out one



STRAIGHT STUD AND PIPE SUBSTITUTED

like the original, a piece of ¾-in. round steel stock was threaded at each end and a piece of ¾-in. steel tubing put on, as shown in the illustration, care being taken that the length equaled the distance between the shoulders of the old stud so that the valve stem would work freely in the yoke.

H. C. WILLIAMS.

Concord, N. H.

Analysis of Boiler Failures

On looking over the list of boiler failures published in the issue of Nov. 7, the first impulse is to wonder if any one class of boilers is responsible for the bulk of the damage or if the lax boiler inspection laws in some states may be held to account for much of the trouble. Or if neither of these, then what factors do work to produce over 350 boiler failures with more than 150 fatalities in 13 months?

To satisfy this curiosity I tabulated the failures by states and by general classes of boilers, as given. The totals show Pennsylvania with 45 failures, an "easy winner," with New York reporting 26, a "poor second." The states are comparable in population and industries, so on the face of this showing, supervision in New York must be very effective and in Pennsylvania very lax. But the difference is almost entirely in the number of water-tube boilers reported, and it seems unlikely that Pennsylvania had more than eight times as many failures in that particular class with other kinds comparable in the two states. The conclusion is that in Pennsylvania there is a more effective system of reporting boiler failures which do not result in loss of life or great damage; therefore, with different systems of reporting, there is little to be gained from a comparison of reports by states.

Turning then to the classes of boilers, one is surprised at the large number of locomotives that explode. Some of these are industrial engines, but 22 are unmistakably in railway service, although reported more incidentally than as an attempt to cover that class of boilers. Presumably a railway locomotive comes daily under the observation of an experienced roundhouse foreman, is frequently cleaned and thoroughly inspected, and is periodically taken out of service and overhauled.

The next class includes heating systems and hot-water heaters, including even kitchen ranges. The safety of this class depends on good design, for they seldom have skilled attendance, are never repaired before rupture and, because of installation in private dwellings, will be the last to receive effective official inspection. It is understood that the list in this particular is very incomplete, reports being made only when damage is notable.

BOILER FAILURES CLASSIFIED BY STATES

State	Population, Census, 1910	Locomotive-Boiler Failures	Water-Heater and Heating-Boiler Failures	Traction, Farm and Portable Boiler Failures	Water-Tube Boiler Failures	Boiler Failures Not Clearly Included in Other Classes	Total Failures	No. Persons Killed
Group I. New England and North Atlantic States—Manufacturing and Mining								
Maine	742,371	...	...	...	...	2	2	1
New Hampshire	430,572	...	...	...	...	1	1	0
Vermont	355,956	...	...	...	...	1	1	1
Massachusetts	3,366,416	2	16	...	1	...	21	2
Connecticut	1,114,756	...	8	...	2	1	11	0
Rhode Island	542,610	...	2	...	1	...	3	0
New York	9,113,614	2	12	3	2	7	26	6
New Jersey	2,537,167	1	6	...	2	3	12	2
Pennsylvania	7,665,111	2	13	2	17	11	45	10
Delaware	202,322	1	...	...	...	...	1	0
Group totals	26,070,895	8	57	5	25	26	123	22
Group II. North Central States—Agriculture and Manufacturing								
Ohio	4,767,121	1	2	1	7	3	14	3
Indiana	2,700,876	1	1	1	2	2	7	0
Michigan	2,810,173	0	2	0	4	3	9	1
Illinois	5,638,591	1	6	2	5	3	17	4
Wisconsin	2,333,860	1	2	0	5	3	11	0
Missouri	3,293,335	1	3	3	0	3	10	3
Iowa	2,224,771	0	7	2	1	2	12	1
Minnesota	2,075,708	0	0	0	0	2	2	2
Group totals	25,844,435	5	23	9	24	21	82	14
Group III. Southern States—Agriculture, Lumbering, Mining								
Maryland	1,295,346	0	3	0	0	2	5	6
West Virginia	1,221,119	2	1	0	0	5	8	21
Virginia	2,061,612	1	1	1	1	1	5	2
North Carolina	2,206,287	1	0	1	0	6	8	9
South Carolina	1,515,400	0	0	1	1	5	7	2
Georgia	2,609,121	0	1	0	1	1	3	0
Florida	752,619	0	0	0	0	3	3	0
Kentucky	2,289,905	0	0	2	0	6	8	11
Tennessee	2,184,789	0	1	1	0	3	5	3
Alabama	2,138,093	3	1	0	2	5	11	9
Mississippi	1,797,114	1	0	0	2	4	7	7
Arkansas	1,574,449	0	1	0	0	3	4	3
Louisiana	1,656,388	3	2	0	1	4	10	18
Oklahoma	1,657,155	2	2	0	0	2	6	6
Texas	3,896,542	4	2	1	0	11	18	12
Group totals	28,885,939	17	15	7	8	61	108	109

The surprise of the table is the record of the much-maligned traction or portable engine. Being high-pressure boilers and much neglected, they are likely to fail with a "real" explosion when they do let go, and so get into the list; but only 26 in thirteen months argues them less dangerous than generally supposed.

The record of failure in the case of water-tube boilers is likely to be incomplete, for from their construction, the damage is slight in the majority of cases; so unless there is some system of collecting data, as is seemingly the case in Pennsylvania, a small proportion of these cases will obtain publicity. The number of fatalities from water-tube boilers is low, being only nine during the period covered.

While an analysis by states was not enlightening, yet when the states were grouped in large areas corresponding

to major occupations, the results were at once of interest, especially if considered from a standpoint of fatalities.

The New England and North Atlantic States, the great manufacturing center of the country, had only 66 industrial boiler accidents (omitting heating boilers), with 22 deaths; while the North Central, agricultural and manufacturing, with slightly less population, had only 59 explosions and 14 deaths. Contrast this record with the great southern group of agricultural and lumbering states with 93 accidents and 109 deaths. These three great divisions have approximately the same populations, yet the danger of death from a boiler explosion is five times as great in the agricultural South as it is in the manufacturing East and seven times as much as in the industrial North.

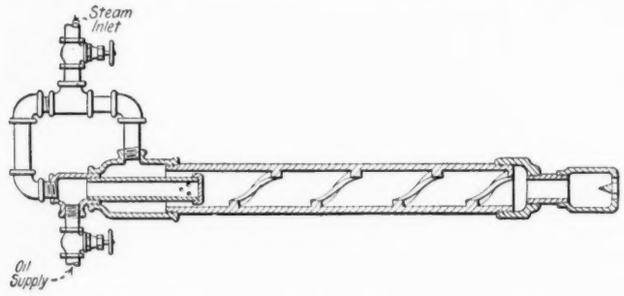
That the accidents are more numerous argues that boilers are entrusted to the care of irresponsible attendants, while the great number of fatalities may come from the proximity of more people; that is, a power plant large or small may be an accepted assembling place for idlers.

Whatever the causes, and they are probably numerous, the lesson of the boiler accidents of the past year is that the great South is the greatest sufferer and is giving the steam boiler a bad name throughout the country.

Lafayette, Ind. GEORGE W. MUNRO.

Oil-Burning Furnace

In the issue of Sept. 26, page 464, there is a description of a home-made oil burner. Whether this is an infringement on at least one patented burner, shown in the illustration, there may be some doubt, but it will be seen upon examination that there are points of marked similarity.



ONE FORM OF PATENTED OIL BURNER

It would be interesting to know the evaporation accomplished per pound of oil and the condition of the boiler shell and tubes after a few months' use. It is hard to see just how atomization of the fuel is accomplished before it enters the furnace.

To get the best results from oil as fuel it must be as finely atomized and vaporized as is possible, or else there will be drops of free oil carried by the draft to the tubes or shell and these, striking the cool surfaces, will cause scale and maybe blistering.

The following is quoted from "Oil Fuel for Steam Boilers," by Strohm:

> Crude oil will not burn in the liquid form; a live coal or a blazing stick may be dropped or thrust into a vessel containing the oil. Instead of firing the oil, the live coal will be quenched or the flame of the stick will be extinguished by the oil, for the simple reason that the oil is vaporized so slowly that the inflammable gas produced is not sufficient to suppport continuous combustion.
>
> The object of atomizing the oil, or dividing it into a fine mist or spray, can now be understood. By separating the body of oil into a great number of fine particles, each particle will have its surface exposed to the heat and will be more readily vaporized than a large bulk of oil. The finer the mist or spray the more easily will the vaporizing occur. If the oil is broken up into a series of drops each 0.1 in. diameter, the ratio of the surface area to the volume of each drop is 60 to 1. But if the drops are 0.01 in. diameter, the ratio of area to volume is then 600 to 1. That is, the drop of oil 0.01 in. diameter will expose ten times as much surface per unit of volume as will the drop 0.1 in. The finer the particles, therefore, the greater the amount of external surface per unit volume exposed to the action of the heat and the more rapidly will the oil turn to vapor.

The burner described is similar in type to models used some years ago and discarded by the designers as lacking in the principal requirement of a good oil burner—namely, assurance of atomization—but the writer in no way asserts that the burner discussed is an intentional infringement of patented designs of hydrocarbon burners.

It is often hard to see where the economy comes in using home-made substitutes when there are so many really good and economical appliances that have been thoroughly tested before being placed on sale, which in most cases represent the work of a number of years of experimenting on the part of the designers.

It is not to be inferred that all home-made articles are inferior. Some of the most valuable apparatus are the direct result of experiments by engineers, and the engineer without initiative is doomed to hold minor positions and to step aside to make way for one who is not satisfied with anything but the best. GROVER C. LONG.

Lakeland, Fla.

Boiler-Room Load Dispatching

"Load dispatching" in the parallel operation of electric generators is common, but why isn't this practice adopted more in the operation of a battery of boilers? It is done to some extent in central stations, but economy could be gained in isolated-plant operation as well. An interesting example came to my attention recently.

A plant of five 200-rated horsepower water-tube boilers carried a practically uniform load of about 700 hp. with the exception of a 200-hp. motor load which came on at frequent and irregular intervals for 5 to 15 minutes at a time. Three boilers should have taken care of this load, but when attempted it seemed impossible to hold the pressure, which would often drop 15 lb. when the "swing load" came on before the fire could be brought up; then steam was lost through relief valves when the load went off, so four boilers were kept on to accommodate the load.

Later, when individual steam-flow meters were installed, the firemen could see what each boiler was doing at all times and "load dispatching" was made possible. Two boilers are fired uniformly at a rate of between 275 and 325 hp., and the third boiler is "floated" and an indicating ammeter in the boiler room announces the coming of that sudden load. By opening the draft on the floating boiler and closing off all the boiler feeds, it is easy to carry the swing successfully. At periods when this load is off, the water level in the third boiler is permitted to rise and the heat stored in it prepares the boiler to meet the next recurrence of the swing load.

Naturally, the cost of operating three boilers is less than that of four. The result was easily accomplished after the boilers were equipped with meters to make load dispatching possible. H. A. HOFFMANN.

Philadelphia, Penn.

Inquiries of General Interest

Separate Generation of Steam for Sterilizing—For a small hospital where high-pressure steam is required for sterilizing purposes and low-pressure steam is used for heating, would it be better to generate all steam at high pressure or employ separate high and low-pressure boilers? W. N. S.

It would be better to employ a small high-pressure boiler for sterilizing purposes for use during winter or summer and separate boilers operated with low-pressure for the steam heating. This will insure no interference of one system with the other, and besides being simple in operation, the annual cost of maintenance should be less.

Refrigeration Capacity of Tank Coils—What should be the capacity of a brine tank having 5,000 lineal feet of 1¼-in. ammonia pipe coils? L. D.

A brine tank should have about 70 cu.ft. of volume and be equipped with about 150 sq.ft. of ammonia pipe coils for each ton of refrigeration capacity per 24 hr. Where 1¼ in. pipe is used for the coils, as 2.3 lin.ft. of 1¼-in. pipe is required for 1 sq.ft. of surface, each ton would require 150 × 2.3 = 345 lin.ft. of 1¼-in. pipe, and with a tank of suitable proportions, 5,000 lin.ft. of 1¼-in. pipe would be suitable for a capacity of 5,000 ÷ 345 = about 14.5 tons.

Steam Required to Heat Water—What number of boiler horsepower would be required for heating 3,000 lb. of water per hour from 62 to 212 deg. F.? L. G.

Each pound of water would require 212 — 62 = 150 B.t.u., and 3,000 lb. would require 3,000 × 150 = 450,000 B.t.u. As one boiler horsepower is equivalent to the evaporation of 34½ lb. of water from and at 212 deg. F. and as each pound so evaporated requires for the latent heat of evaporation 970.4 B.t.u., one boiler horsepower is equivalent to 34½ × 970.4 = 33,479 B.t.u. per hr., and to heat 3,000 lb. of water per hour under the conditions stated would require 450,000 ÷ 33,479 = 13.4 boiler horsepower.

Discharge and Power Developed by Pump—What would be the discharge and the net horsepower developed by a 10x12-in. pump running at 100 strokes per minute, pumping against a head pressure of 185 lb. per sq.in. E. K.

The piston displacement would be (10 × 10 × 0.7854) × 12 × 100 = 94,248 cu.in. per min., and as one gallon equals 231 cu.in., without any allowance for slippage the discharge would amount to 94,248 ÷ 231 = 408 gal. per min., and pumping against a head pressure of 185 lb. per sq.in., the net energy developed would be $185 \times (10 \times 10 \times 0.7854) \times \frac{12}{12} \times 100 =$ 1,452,990 ft.-lb. per min., or $\frac{1,452,990}{33,000} = 44.03$ hp.

Steam Required to Melt Ice—How many pounds of steam at an absolute pressure of 100 lb. per sq.in. would be required to melt 20 lb. of ice at 24 deg. F.? H. K. W.

The specific heat of ice is 0.504. For raising each pound of the ice from 24 deg. F. to 32 deg. F. would require (32 — 24) × 0.504 = 4.032 B.t.u., and for conversion into water after reaching a temperature of 32 deg. F., each pound would require the addition of 144 B.t.u. called the latent heat of fusion. Hence to melt 20 lb. of ice at 24 deg. F. would require 20 × (4.032 + 144) = 2,960.64 B.t.u. and as a pound of steam at an absolute pressure of 100 lb. per sq.in. contains 1,186.3 B.t.u. above 32 deg. F., to melt the ice would require 2,960.64 ÷ 1,186.3 = 2.5 lb. of steam.

Advantages and Disadvantages of Mud Drums—What are the advantages and disadvantages of having a mud drum attached to a boiler? J. H.

The advantages of a mud drum are to afford a part of the boiler where the circulation is sluggish and where solid matter may settle and be blown off in place of becoming baked on the heating surfaces of the boiler. The disadvantages are that the mud drum, or its connections, may easily become completely stopped up and give more trouble in clearing them than to wash out the same amount of sediment spread throughout the boiler. In case of stoppage of the mud drum connections when exposed to heat from the fire they may become burnt out, or if kept clear they usually are weakened by pitting and corrosion more rapidly than any other part of a boiler.

Delivery of Air-Lift Discharge to Distant Tank—Water is to be raised by an air lift from a driven well under one end of a building 150 ft. long, and is to be discharged into a tank at the other end of the building, about 40 ft. above the ground. Should the discharge pipe be run at an inclination from the top of the well to the top of the tank, or is there a better method? H. W. B.

The discharge pipe should be carried up vertically out of the well to a sufficient height for delivering the water to the tank by gravity. For turning the water into the delivery pipe, the upper end of the discharge pipe should be provided with a return bend, or a short goose-neck fitting, with a good-sized air vent at its highest point. The delivery pipe may be run from the top of the discharge pipe to the tank by any course found desirable.

Why Hot-Water Pump Becomes Steambound—What causes the water cylinder of a hot-water pump to become steambound when handling water at 150 deg. F.? R. W.

The lower the pressure of a liquid the lower the temperature at which it vaporizes, and water at a given temperature is rapidly converted into vapor when subjected to less pressure than the pressure of vaporization corresponding with the given temperature. When the water is at a temperature of 212 deg. F., steam forms at atmospheric pressure, or 14.7 lb. absolute, and when at 150 deg. F. vaporization occurs at 3.714 or practically 4 lb. absolute. Hence if the suction water at 150 deg. F. is not delivered at sufficient pressure to keep the pump cylinder filled behind the piston at a pressure greater than 4 lb. per sq.in. absolute, or greater than that which would be equivalent to about 20 in. vacuum, the water bursts into steam, causing the cylinder to become steambound.

Reducing Frictional Loss in Pump Suction Line—A 2-in. feed-pump suction line from an open heater is 2 in. diameter and the pump is 8 ft. below the average water line in the heater. Will the suction pressure at the pump be increased by making the line 4 in. with the suction connection left 2 in. as at present? O. S.

When the pump is not running, the static, or standing pressure will be the same for all sizes of the suction pipe. But when there is any flow taking place, a part of the head is lost in friction and the pressure available at the pump will be greater using a larger suction pipe. Practically for the same length of pipe and roughness of pipe surface and the same rate of flow, the loss of pressure from friction varies inversely as the fifth power of the pipe diameter. Hence the loss of friction sustained from use of a 4-in. line would be only $\frac{2^5}{4^5}$ or about 3 per cent., of the loss from use of a 2-in. pipe.

Setting Spool on a Duplex Pump—How is it determined whether the rocker-arm spool on a duplex pump is set in the proper position? J. L.

Move the piston rod that carries the spool until the steam piston on the same rod strikes first one end and then the other of the steam cylinder, and for each extreme position make a mark on the piston rod even with the end of the stuffing-box. Make a mark on the rod midway between these marks and move the rod so this middle mark will come even with the stuffing-box. The piston rod that carries the spool will then be in the middle of its stroke. Remove the valve-chest cover and observe whether the lost motion of the valve will permit the middle of the valve to be moved the same distance each side of a point midway between the outside edges of the steam ports. If there is not the same amount of lost motion available, the lost motion can be equalized by altering the setting of the spool on the piston rod which is at half-stroke; but before disturbing the spool from its old position it would be better, if possible, to make an equalization of the lost motion by changing the lost-motion adjustment that is usually provided on the valve rod. If the rocker arms are not square across the shaft when the rod that carries the spool is at half-stroke, there will be a difference of angularity, which will require adjustment of the lost motion to prevent short-stroking.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—Editor.]

The Proportioning of Surface Condensers*

By George A. Orrok

SYNOPSIS—Formulas are given for the proper proportions for surface condensers, from the latest experimental data by the author and others. This paper is practically an extension or continuation of one presented by the same author at the A. S. M. E. annual meeting in 1910.

During the discussion of my paper on "The Transmission of Heat in Surface Condensation,"[1] I was asked to present formulas covering the application of the results of my experiments to the design of surface-condensing apparatus. Since the appearance of the paper there have been a number of papers on allied subjects whose authors have approached the subject from a somewhat different standpoint, and the conclusions presented have been of varying character and usefulness in the design of surface-condensing apparatus. Only one author, Loeb,[2] has presented new experimental data which can be used for checking the heat-transfer constants, but considerable mathematical work has been done along the line of following out Jordan's deductions from Osborne-Reynolds' statement of the law of heat transfer.

I propose in this paper to discuss the state of the art of "heat transfer in surface condensation" and to establish design formulas for use in proportioning condensing apparatus.

The law of temperature rise of the water in a condenser tube is still unknown. My own tests led me to believe that this law departed somewhat from the logarithmic law as stated by Smith and Josse, but their results are sufficiently variant to allow for a slight modification. Loeb, however, has presented a set of tests with plotted curves, from which he deduces that the law is of the exponential form, with approximately 0.9 as the exponent. My plotting of his numbers places the exponent nearer 0.8, both of which are not far from my adopted figure of 0.875. These variations are not of prime importance for practical design, and indeed may be caused by the apparatus used in the making of the experiments; and I am still of the opinion that we may use $N = K\theta^{0.875}$ as the basis of our work, N being the total heat transfer per square foot per hour in B.t.u., θ the temperature difference, and K a constant determined by experiment.

It has been stated in "Engineering" (London, January, 1914) that the extreme variation in the results of heat-transfer experiments has been caused by a neglect of the variation due to the viscosity of the water, and quite an extended argument was given to show that some of these experiments were reconciled when the correction was applied. Wilson has carried this method to its logical conclusion in his paper, "A Basis for Rational Design of Heat-Transfer Apparatus,"[3] lately presented to the society. Our work in the design of surface condensers, however, is mainly concerned with a very small variation in temperature, the upper limit of which is fixed by the vacuum carried at somewhere between 80 and 90 deg. F., while the lower limit in America is between 65 and 70 deg., and in Europe possibly a few degrees lower—in all a variation of perhaps 20 deg. In the winter we can carry good vacuums with low heat transfer and our troubles are few, but the problem is the summer problem, and here the difference in viscosity is small. As a matter of fact, I believe Osborne-Reynolds' straight-line law does not apply where there is a change of state at either side of the metallic surface. Observers making use of this hypothesis have been frequently misled by the bunching of the results in the condenser range, with the consequent spreading of the results outside this range.

There has been considerable comment on the effect of stream flow and turbulent flow on the heat transmission, and as there is a marked change in the friction characteristics between the two states of flow, the conclusion has been drawn that there will be a similar effect on the heat-transmission characteristics. Osborne-Reynolds investigated this subject and gave formulas for the critical velocities. He finds two critical velocities: The lower, which we may call Vc, below which all motion is stream-line and if disturbed artificially will return to stream-line flow; and an upper critical velocity, Va, above which all motion is turbulent. Between the two is a field in which stream-line motion may be maintained if no artificial causes upset it, or turbulency may be set up and will maintain itself when so started. He gives formulas for these two velocities, which, following Parker, are

$$Vc = \frac{0.0388P}{D} \text{ and } Va = \frac{0.2458P}{D}$$

where D is the internal diameter of the tube in feet and P is Poisseuille's ratio; that is, the ratio between the viscosity and density of the water. If the values of v = viscosity and δ = density be taken in C.G.S. units,

$$P = 56.2\frac{v}{\delta}\begin{cases} = 1.000 \text{ at } 0 \text{ deg. C. (32 deg. F.)} \\ = 0.734 \text{ at } 10 \text{ deg. C. (50 deg. F.)} \\ = 0.455 \text{ at } 30 \text{ deg. C. (86 deg. F.)} \end{cases}$$

This agrees with Osborne-Reynolds' value, which is

$$P = \frac{1}{1 + 0.0336T + 0.000221T^2}$$

where T is the temperature in centigrade degrees (not the absolute temperature, as stated in Wilson's paper). The table of correction factors in Wilson's paper may be used as a table of P by multiplying the correction factors by 0.625, thus correcting the values to 32 deg. F. The critical velocities for a 1-in. No. 18 B.w.g. condenser tube will then be as follows, T being the mean temperature of the water:

T Deg. F.	40	50	60	70	80	90	100	115	130	150
Vc	0.50	0.422	0.362	0.318	0.278	0.25	0.224	0.192	0.166	0.14
Va	2.84	2.400	2.060	1.810	1.580	1.42	1.270	1.090	0.945	0.80

In condenser practice and in most of the apparatus for heat-transfer experiments it is nearly certain that the flow is turbulent above Vc. Velocities from 6 to 10 ft. per sec. are the common range in modern surface condensers, so that in every practical case the critical velocity need not be considered.

CONDITIONS DETERMINING VALUE OF COEFFICENT K

Surface-condensing apparatus is never tested to the capacity of the surface to transfer heat, and Gibson and Bancel[4] have shown this in their characterizing the "active" and "inactive" zones in a surface condenser. The condenser must be designed for the maximum load that may be put on it when the entering water is at its maximum temperature, and additional surface must be installed as a factor of safety against dirty, oxidized tubes and the presence of undue amounts of air. The depression of the hotwell temperature below the vacuum temperature, a well-marked phenomenon in many condensers, may be eliminated by good design, and many tests by careful investigators have been reported in which the depression was zero. Certain designs of the dry-tube type may give hotwell temperatures somewhat higher than the average temperature in the condenser. The hotwell depression is especially marked where drowned lower tubes are used.

Neilson and others have objected to conclusion (b) in my 1910 paper[5] that the heat transmission is approximately proportional to the square root of the cooling-water velocity. Within the condenser range the experiments may perhaps be better represented by $KV_w^{0.6}$ instead of $KV_w^{0.5}$. Weir ("Trans." I. E. S. S.), in his paper, read Oct. 22, 1912, gives a curve for the relation of U to Vw for design purposes. The curve corresponds very closely to $U = 250\ V_w^{0.6}$, the maximum variation being less than 2 per cent. It is possible that a closer agreement might be secured by using more figures in the exponent, but such a procedure is hardly necessary, as probably we have already exceeded the accuracy of our experimental apparatus. The effect of air in reducing heat transmission has been shown in my 1912 paper,[6] and a term introducing the second power of the pressure ratios recommended to allow for it in design. This subject is still unsettled and will remain so until Smith's experiments are repeated on a proper scale, with known amounts of air present in the condenser. We may

*For presentation at the annual meeting of the American Society of Mechanical Engineers, New York, Dec. 5-8, 1916. The paper is from an advance copy. All papers are subject to revision.

[1] "Trans." A. S. M. E., Vol. 32, p. 1139.

[2] "Jour." A. S. Nav. Eng., May, 1915.

[3] "Trans." A. S. M. E., Vol. 37, p. 47.

[4] "Trans." A. S. M. E., Vol. 37, p. 975.

[5] "Trans." A. S. M. E., Vol. 32, p. 1135.

[6] "Trans." A. S. M. E., Vol. 34, p. 713.

say that the term $\left(\frac{Ps}{Pt}\right)^2$ represents the reduction of heat transmission by air, with a possible variation of 10 per cent. The difficulty is in obtaining a figure for the amount of air present and its temperature. The use of the air bell enables the operating man to keep his leakage down to the minimum, and where water-jet air pumps are used, the testing dry vacuum pump and air bell will usually pay for themselves in a very short time.

The attempt to find a better tube material than admiralty brass has failed, and the standard tube today is a heat-treated admiralty-mixture tube whose material coefficient is 0.98. This coefficient can now be neglected. A number of experiments with dirty and oxidized tubes have been made, but since it is possible to clean a tube by mechanical means and secure the original heat transmission, the cleanliness coefficient may be also neglected in design and only used in checking up a condenser test where allowance must be made for a dirty tube condition.[7]

Assuming that I had practically air-free steam in the experimental apparatus and clean tubes, the value of K is $U\theta^{0.125}/V_w{}^{0.6} = 470$. The value 630 given in my paper was arrived at by assuming an air pressure of about 0.065 in. of mercury. If the air-term influence be taken to the second power, K = 570. In both cases 90 per cent. cleanliness and 0.98 for material were assumed.

We know that the results of single-tube experiments may be approached in real condensers, and the closer the approach when the condenser is supplied with sufficient steam, the better the performance of the condenser. We know that they never can be approached with light loads or with colder water, because only so much heat is transferred as is present. This definitely prevents the use of Jordan's "mass flow" formulas or the electric resistance simile. These hypotheses can be true only where no change of state takes place, and this condition is entirely foreign to heat transfer as met with in condenser practice.

We may now put down the following principles:

a The law of temperature rise in the tube is of the exponential form, with 0.875 = 7/8 (0.9 or 0.8, perhaps) as the exponent.

b We may neglect viscosity for design purposes in America where the water temperature is 65 to 70 deg. F. and the vacuum 28 in. and over.

c We may also neglect critical velocity, since all condenser velocities are far above it.

d For velocities in condenser practice we may take K as varying as the 0.6 power of the velocity.

e The reduction in heat transmissive power due to air is very approximately covered by the use of a term $\left(\frac{Ps}{Pt}\right)^2$ as a reducing factor of K.

f For design work we may reduce the value of K once for all to account for the cleanliness of the tube and the material itself.

g The value of K will then be reduced to somewhere between 300 and 400 for design purposes, say 325 for average good working.

THE AUTHOR'S METHOD

Condenser specifications usually call for the condensation of a certain amount of steam per hour, W (lb.), and the maintenance of a vacuum referred to standard barometer or absolute pressure, Pv, with condensing water at a certain temperature, t_0. The quantity of condensing water Q, the hotwell temperature ts, the power used by the auxiliaries and the steam consumption of the auxiliaries may be also specified, but the problem is reasonably determinate when W, Pv and t_0 are known. It is important that the place of measurement of the vacuum Pv be specified, as there is a well-defined drop through most condensers, the vacuum being greatest at the air-pump suction, less in the condenser, and least at the prime-mover nozzle. This drop may amount in well-designed condensers to 0.2 in. of mercury. The specified vacuum should be measured at the prime-mover nozzle, and the designer, according to his judgment, will then allow 0.1 to 0.2 in. for the drop in the condenser.

The absolute pressure in the condenser will then be 29.92 — (vacuum + 0.2 in.) = Pv. The steam tables may now be consulted and t_s = the temperature corresponding to the vacuum, γ = the total heat and q = the heat of the liquid be taken therefrom. The final temperature of the condensing water approaches ts, and for close work may be $t_1 = ts - 5$ deg. In ordinary practice, $t_1 = ts - 7$ deg, or in some cases 8 deg. or 10 deg. The ratio of condensing water to steam condensed, which is $R = \frac{\gamma - q}{t_1 - t_0}$, may next be found. Many designers consider it close enough to use 1,000 for γ — q, on account of the moisture in the exhaust steam, and some few use 968. I prefer to use γ — q, not on account of its accuracy but as a slight factor of safety. Q, the quantity of condensing water = WR in pounds per hour.

At this point the size and thickness of the condenser tubes as well as the water velocity must be chosen. Most of the large installations in eastern United States use 1-in. tubes on account of bad water conditions, although it has been stated that smaller tubes are more efficient (vide Weighton, Neilson and Weir). There are no definite experiments to decide this point, although from Loeb's work on ¾-in. tubes we may deduce a value of K = 600 against K = 470 for my experiments on a 1-in. tube. Nevertheless, it is doubtful if anything is saved by the use of anything smaller than ¾ in. when the pumping head is considered. Tubes of 1¼-in. diameter have also been used, but the consensus of opinion seems to be that a 1-in. tube can be cleaned better, keeps in good condition longer and can be made better than either smaller or larger tubes. Let us take 1-in. tubes, No. 18 B.w.g., as standard. The formulas may readily be altered for other sizes of tubes when the constants are known.

With 1-in. tubes velocities from 7 to 10 ft. per sec. are now usual. We may take 8 ft. per sec. as the standard value for Vw.

The number of 1-in. tubes in one pass will be given by the formula

$$n = \frac{Q}{990 V_w}$$

The length of water travel (l), or the total tube length, may be found from

$$l = \frac{30.8Q}{325 V_w 0.6 n}[(t_s - t_o)0.125 - (t_s - t_1)0.125]$$

and the total tube surface S from

$$S = 0.262\ nl$$

With 1-in. tubes from 40 to 80 will occupy 1 sq.ft. of tube-plate area, depending on the spacing and general design. The average will be about 60, making the cross-sectional area of the condenser (sq.ft.) equal to (n × number of passes) ÷ 60. If there are two passes, the length of the condenser will be L = ½l + depth of water boxes.

BEST TUBE LENGTHS AND TEMPERATURE RISES

The complete paper gives the condenser formulas proposed by Neilson in his paper read before the Institution of Engineers and Shipbuilders of Scotland, together with those published in Morrow's "Steam Turbine Design" and in Bauer and Lasche's "Marine Steam Turbines." These writers use the arithmetical mean for the mean temperature difference. Neilson says: "Equations for θ_m involving the use of hyperbolic logarithms are not to be recommended for condenser design," the reason being that the steam-air mixture in the condenser is not homogeneous. Weighton, upon whose experiments Morrow's work is largely founded, did not consider θ at all in his paper. Many other authorities follow this rule also, and I must acknowledge this position to be correct provided that equal increments in the temperature rise of the water in the condenser tube accompany equal increments of length. The tests of Smith and Josse as well as my own have definitely proved that this is not so. Thermometers placed in the water boxes of any two- or three-pass condenser will also show this fact very plainly.

Now for each curve of temperature rise except the arithmetic there is a definite relation of l/d which is best for any given condition. Under the arithmetical law any values of d, n and l that will give the necessary surface should be equally efficient, and 10 tubes 100 ft. long should work as well as 1,000 tubes 1 ft. long from the heat-transfer standpoint.

The differences between the logarithmic law and the exponential with an exponent between 0.9 and 0.8 are quite small, but the length of the tube required by the formulas is considerably shorter using the logarithmic formula. These length formulas may be derived from the expressions for S given in the fourth column of the table on p. 1152, Vol. 32, "Trans." A. S. M. E.

Taking the steam temperature ts at 90 deg., the entrance-water temperature t_0 at 70 deg., and the discharge at 80 deg., with a water velocity of 8 ft. per sec. and 1-in. tubes, I figure the best tube lengths and temperature rises as follows:

	Tube Length, Ft.	Rise In Deg. F.
Arithmetical Law	23.2	0.4310 deg. per ft. of tube
Logarithmic Law	24.0	0.4918 deg. in first foot
Exponential Law (exponent = 0.875)	26.8	0.5624 deg. in first foot

It is to be hoped that some investigator will definitely settle this question on which so much in condenser design depends.

[7] Report of Com. on Prime Movers, Natl. Elec. Light Assn., 1916.

Pressure Oil-Film Lubrication*

By H. T. Newbigin

SYNOPSIS—Describes the Michell thrust bearing—which, like the Kinsbury bearing (see "Power," May 13, 1913) attains the pressure oil film lubrication impossible with ordinary single and multiple collar thrust bearings. Extremely heavy loads are carried at comparatively high speeds and with a low power consumption. This type of bearing is being widely applied to turbine installations abroad.

Without lubrication a bearing will not run without excessive wear, and without artificial cooling no bearing with oil lubrication will run continuously if the temperature rises above 150 deg. F., because at about this temperature most oils begin to carbonize. The efficiency of a bearing must therefore be such that the temperature due to the heat generated by its friction, minus that dissipated by radiation and conduction, does not exceed this figure.

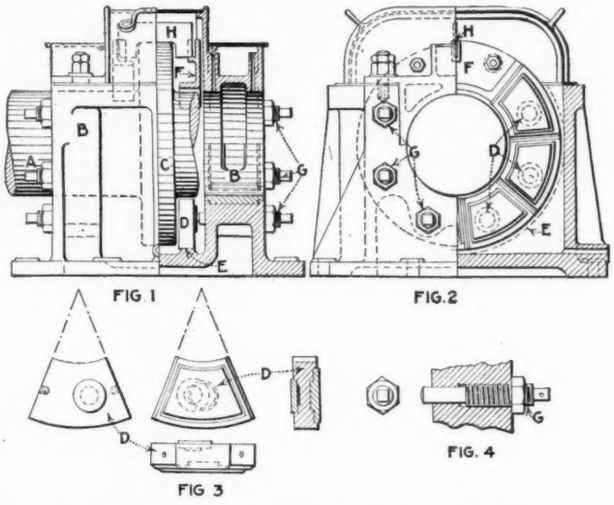
In order to reduce the friction between two rubbing surfaces it is necessary to put something between them, and bearings may be classified into those in which this is a hard material such as steel balls or rollers and those in which it is a viscous substance like oil or grease.

The first class does not consist merely in introducing balls or rollers between the relatively moving surfaces in the primitive forms of journal and thrust bearings; they are highly specialized machine parts designed to utilize to the greatest advantage the rolling action of balls or rollers in reducing friction, and their design is evolved from a study of this action. On the other hand (except in the cases to which reference will be made later), the second class consists merely in applying a lubricant to the primitive forms or to some slight modification thereof. They are not designed to utilize the action of the lubricant on any principle; the lubricant is merely added to the primitive forms because it has been found to make them work better. Ball and roller bearings have attained a remarkable degree of perfection, and they are admirably suited for bearings in which the loads to be carried are comparatively light or in which the motion is intermittent; but they are not suited to carry heavy continuous loads, especially at high speeds.

In ball bearings the steel balls make point contact with hardened-steel races, and the balls tend to flatten at the point of contact. Under excessive continuous loads this slight deformation of the balls causes their outer surfaces to shell off, and the chips get under the other balls and ultimately destroy the construction of the bearing. The life of the balls is limited, frequent renewals are necessary, and to effect these renewals it is essential to dismantle the bearing.

In roller bearings the rollers make (or are supposed to make) line contact with the housing and with the shaft. Although they are able to carry heavy loads, it is difficult to maintain correct alignment, and any slowing of the rollers sets up a heavy end thrust against the cage in which they work. Furthermore, as the rollers bear directly on the shaft, the constant rolling action tends to laminate the surface and so wear it away. In roller thrust bearings it is necessary to make the rollers conical, and as they therefore have a heavy radial thrust this type of bearing is not much used.

The advantage of both ball and roller bearings is their low starting friction; for this reason they are especially suitable for intermittently moving machinery, but in continuously running machinery where a low starting friction is of less importance than a low running one, it is obviously a great advantage to have the rubbing surfaces separated by something more easily replaceable than either balls or rollers, especially if it is something that can be continuously replaced without stopping the machine, and the more so if it is also capable of being used in high-speed bearings as a medium for carrying away the heat generated by friction from the actual surface of its origin.



FIGS. 1 TO 4. THE MICHELL THRUST BEARING

Figs. 1 and 2—Longitudinal and end sections of bearing. Fig. 3—One of the pivoted sectors that form the surface of the stationary member of the bearing. Fig. 4—Screw for adjusting sectors

It is with the second class of bearings—those in which the surfaces are separated by a fluid such as oil in the case of high-speed and grease in the case of slow-speed bearings—that this paper is more immediately concerned. The use of a lubricant for the purpose of reducing friction is old, but the study of its action, and more especially the manufacture of bearings designed to utilize this action to the best advantage, is quite modern.

The action of a lubricant is two fold. It first of all alters the nature of the rubbing surfaces, thereby reducing friction (and this is the commonly accepted justification for its use), but under favorable conditions it goes much farther than this and automatically generates a high-pressure oil film between the surfaces, entirely eliminating metallic contact and thereby enormously reducing the friction. This is what is now called "pressure oil-film lubrication." It occurs to a limited extent in most journal bearings, but does not occur in ordinary collar-thrust bearings.

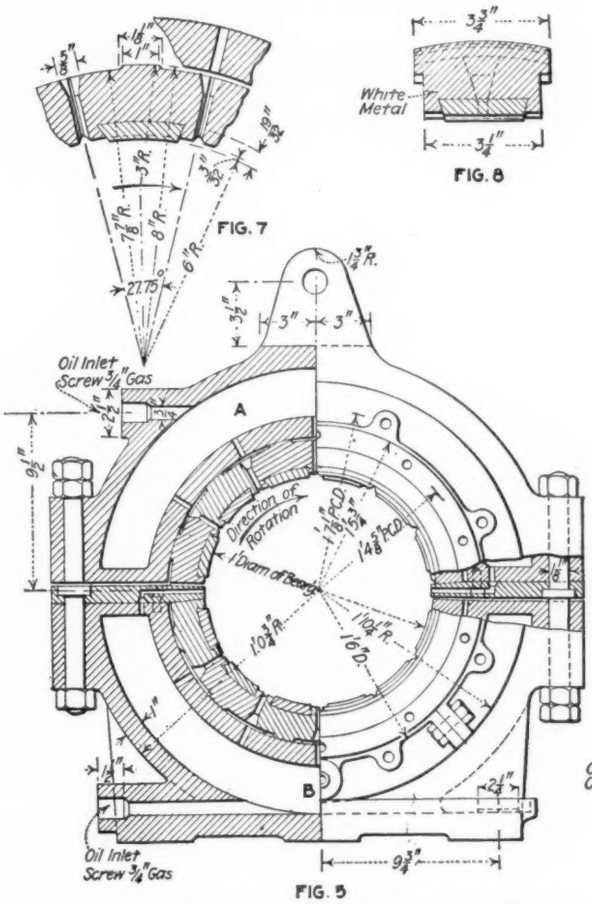
TEST OF EXPERIMENTAL MICHELL JOURNAL BEARING, MAY, 1916

Date and Duration of Test		Total Load	Bearing Pressure Lb. per Sq. In.	Revs. per Min.	Surface Speed Ft., Min.	Amperes	Volts	Horse-power Input	Oil Supply				Friction Horsepower from Heat to Oil	Coefficient of Friction	Actual Friction
									Final Inlet Temp. F.	Final Outlet Temp. F.	Rise of Temp. F.	Flow of Oil Lb., Min.			
May.	Min.	Lb.							Deg.	Deg.	Deg.				Lb.
18	45	.....	...	585	1,840	16.5	406	9.2	68	84	16	12.6	1.9	.....	.....
18	105	2,400	145	620	1,950	14.5	403	7.9	79	99	20	14.8	2.8	0.0099	47.5
18	105	3,600	220	615	1,930	16.0	395	8.6	84	101	17	14.3	2.3	0.0054	39.2
19	60	4,800	290	605	1,900	16.6	382	8.6	83	100	17	15.6	2.5	0.0045	43.7
19	40	6,000	370	615	1,930	16.9	395	9.1	84	102	18	17.6	3.0	0.0043	51.6
19	75	7,300	440	607	1,907	18.9	391	10.0	84	102	18	18.7	3.2	0.0038	55.4
19	45	8,500	520	605	1,900	19.0	395	10.2	83	99	16	19.0	2.9	0.0029	50.1
19	60	9,800	600	618	1,940	20.4	395	10.9	71	93	22	19.0	4.0	0.0034	67.6
20	90	11,700	700	611	1,920	21.0	391	11.1	76	100	24	19.7	4.5	0.0033	77.2
20	30	14,800	900	620	1,950	26.5	400	14.4	77	102	25	22.7	5.4	0.0031	91.7
24	30	.....	...	1,315	4,130	23.0	390	12.2	76	95	19	23.0	4.1	.....	.....
24	60	2,400	145	1,320	4,140	27.8	392	14.8	74	96	22	26.4	5.5	0.0091	43.7
24	45	5,500	330	1,320	4,140	29.8	390	15.8	77	104	27	25.2	6.4	0.0046	51.1
24	60	8,500	520	1,303	4,100	40.0	398	21.6	82	117	35	33.0	10.9	0.0051	87.5
25	60	11,700	700	1,324	4,140	50.0	382	26.0	76	111	35	37.3	12.2	0.0042	98.3
25	105	11,700	700	1,317	4,140	42.0	390	21.2	73	112	39	31.2	11.5	0.0039	91.2
25	30	14,800	900	1,320	4,140	45.5	400	24.7	76	117	41	33.0	12.7	0.0034	100.4

*Paper read before Section G of the British Association at Newcastle, and abstracted from London "Engineering."

Wedge-shaped oil films cannot occur in collar-thrust bearings; hence their inefficiency and low carrying capacity.

It was left to an Australian engineer and mathematician, A. G. M. Michell, of Melbourne, not only to complete Osborne Reynolds' theory, but also to show how its teaching can be applied in practice to the improvement of both thrust and journal bearings. In a paper published in "Zeitschrift für Mathematik und Physik" in 1905, on "The Lubrication of Plane Surfaces," he gave the complete mathematical solution of Reynolds' theory as applied to plane rectangular surfaces. And on the assumption that the thickness of the oil film at the entering edge is twice as great as at the leaving edge, he showed how lines of equal pressure within the film can be plotted and how the center of resultant pressure can be determined for plane rectangular surfaces of varying proportional cross dimensions. He also demonstrated practically that a rectangular block pivoted at its point of resultant pressure will automatically assume an angle to an opposing lubricated surface, depending on the speed of rubbing, viscosity of the oil and pressure. On this principle he made his now well-known thrust bearing.



FIGS. 5 TO 8. MICHELL JOURNAL BEARING FOR LARGE AND HEAVY WORK

Fig. 5—Notice that the bearing surface is divided into many parts, each free to adjust itself. Fig. 6—Partial section of same bearing. Figs. 7 and 8—Details of blocks bearing surface

The result of Mr. Michell's work has been to enable lubricated thrust and journal bearings to be designed with the principles of oil-film lubrication as a basis, in the same way as ball and roller bearings are designed with the ball or roller as a unit, and as distinguished from the mere application of oil to the primitive forms of these bearings. The essential feature of the Michell bearings is the subdivision of the stationary surface into a number of blocks or pads, each pivoted at its back and so free to assume a slight angle with its contacting surface. Bearings designed on this principle differ radically from the primitive forms of journal and thrust bearings.

Taking the case of the thrust bearing first, the Michell thrust bearing differs from the older type in having only one collar, the multiplicity of collars in the older type having been necessitated by the low carrying capacity of parallel rubbing surfaces, as distinguished from the high carrying capacity of those in which the fixed surface is subdivided and made free to assume the angle to the opposing collar necessary for the formation of oil pressure within the film.

The importance of efficiency in machinery is not merely a question of economy of power or fuel; it also controls the practicability of a design, and the design of bearings is an instance of this. For example, in the design of a large multicollar thrust bearing (which is merely an elaboration of the primitive form) the problem the designer has to solve is governed by the efficiency of this form. He has given a shaft of a certain diameter, revolving at a certain speed, and which has to withstand a certain thrust. The resistance to turning will be about 0.03 of that thrust, and the greatest load that the bearing surfaces will carry with safety is about 50 lb. per sq.in.

To bring the pressure down to this figure, he may use either a few collars of large diameter or a number of collars of small diameter. If he does the former, he increases the radius at which the friction acts, and so the power absorbed and the heat generated; if he does the latter, it becomes increasingly difficult to maintain an equal distribution of the load among the collars, especially under the variations of expansion due to the heat generated when the bearing is at work. Furthermore, whatever compromise he makes, there comes a point beyond which the size, load and speed cannot be increased because, owing to the high coefficient of friction, the heat is generated more quickly than it can be dissipated by radiation and conduction, even with the aid of water cooling. This point was reached in the case of the thrust bearings in geared turbine-driven vessels, and partly because the bearings were found to be less able to withstand thrust under the uniform turning movement given by this type of engine than under the varying turning movement given by reciprocating engines. It therefore became necessary to find a form of thrust bearing in which the coefficient of friction is lower than that in the primitive type. The Michell thrust bearing, which goes to the root of the matter and is designed from the point of view of the action of the lubricant in automatically generating a pressure oil film between the surfaces, has formed a solution of the difficulty. It has a coefficient of friction of about 0.0015 as against 0.03, and carries 200-300 lb. per sq.in. with a much greater factor of safety than the primitive form has at 50 lb. The subdivision of the fixed surfaces into a number of segmental tipping blocks or pads is the essential feature of all thrust bearings made on this principle, but there are many variations in the design of the housing and method of carrying the tipping blocks, depending on the particular use to which the bearing is to be put. Figs. 1 and 2 show sectional side and end views of one form in which marine thrust blocks are made. The shaft A is supported in two journal bearings B, one on each side of a single collar C, which bears against two series of segmental pivoted blocks D, arranged in the form of two inverted horseshoes, the one for "ahead" and the other for "astern" thrust.

The blocks D, each of which is pivoted somewhat behind its center on the ends of the screws G, rest on two ledges E concentric with the shaft. They are prevented from rotating with the shaft by stops F, by removing which they may be taken out without disturbing the adjustment of the screws G or lifting the shaft. Figs. 3 and 4 show a detail of one of the blocks D and of its screw G which is employed for adjusting the sectors.

The body of the housing forms an oil well in which the collar revolves, and a scraper H is provided to scrape off the oil brought up by the rotating collar for the purpose of lubricating the upper blocks.

This type is self-contained as regards lubrication, and in the case of large sizes or those running at a high speed, the body of the bearing is water-jacketed. The friction is about one twenty-fifth of that in the multicollar type of thrust bearing.

In the case of the thrust bearings in steam turbines the type adopted is somewhat different. The blocks are symmetrically disposed around the faces of the collar, and each series is mounted on a ring partly spherical on one face, the convex surfaces of which are outward and rest on correspondingly spherical seats for the purpose of automatically distributing the load among the blocks. The blocks are mounted on the faces of the rings next the two sides of the collar against which they pivot, either along radial lines or on rounded pins. This type is entirely inclosed and is supplied with an oil circulation by means of an independent pump. The oil passes through an oil cooler on its course, thereby removing the heat generated by friction from the actual surface of its origin. The mean rubbing speed sometimes exceeds 100 ft. per sec. Slow-speed bearings are made on the same principle with grease lubrication.

Michell thrust bearings now running are in sizes varying from 1 to 15 in. diameter of shaft, and larger sizes are in the course of construction. They are receiving wide application in steam-turbine work. The same principle is now being applied to journal bearings.

In lubricated journal bearings of the primitive type, the phenomenon of pressure oil-film lubrication occurs naturally, owing to the slight shifting of the center of the shaft in relation to the center of the brass, but its occurrence is much less marked in the case of bearings of large diameters, probably because of the greater oil clearance that is necessary in large sizes and to the extreme thinness of the oil film. For example, a journal bearing two or three inches in diameter will run satisfactorily under a pressure of 300 to 400 lb. per sq.in., but it is not found advisable to load large bearings above 100 lb. even with a forced oil circulation.

The pressure oil film occurs only along a narrow strip in the primitive type, and the remaining surface merely forms a brake on the rotation of the shaft, so that the designer is again restricted and can only reduce the pressure to the limit found safe in practice by increasing the length of the bearing. But by subdividing the circumferential surface into a number of segments, each of which is pivoted at its back and thereby free to form an independent pressure oil film between its rubbing surface and the shaft, the number of the pressure oil films can be increased, so that the full projected surface of the bearings becomes effective for carrying load, and the brake surface is eliminated. The friction is thus reduced, the load-carrying capacity increased and the bearing shortened.

A series of tests has recently been run on a Michell journal bearing by Messrs. Cammell, Laird & Co., Ltd., Birkenhead. Figs. 5 and 6 show details of the experimental bearing.

As will be seen from Figs. 5 and 6, the bearing surface is divided into 12 segments, each of which is pivoted on a rib at its back, so that it is free to lift at its leading edge to allow the necessary wedge-shaped oil film to form. These segments are shown in detail by Figs. 7 and 8.

The faces of the segments or blocks are lined with white metal, each surface being 2 in. square, giving 48 sq.in. of rubbing surface, the equivalent projected area of each half of the bearing, 16½ sq.in.

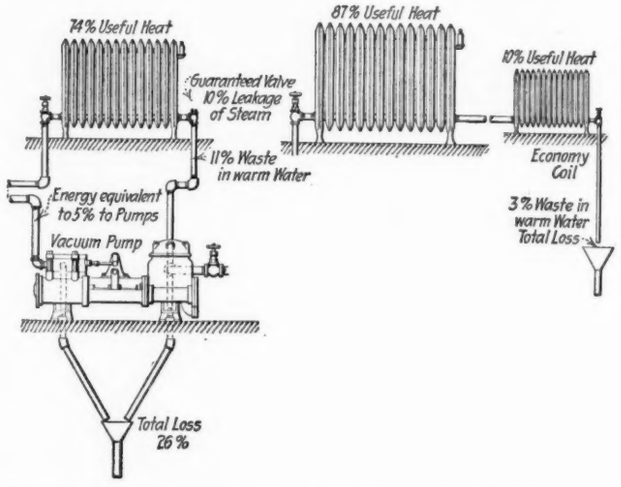
In addition to the segments being free to tilt, the seat on which they rest is partly spherical, thereby making the bearing also a swiveling one. A circulation of oil was passed through the bearing, entering it between each pair of blocks from the chambers A and B and escaping at D. The bearing was driven by means of an electric motor, and the ammeter and voltmeter readings were recorded. Each run was continued until the oil temperature ceased to rise. The ingoing and outgoing temperatures of the oil were also recorded, together with the weight of the oil passing and the revolutions per minute.

The table gives the results observed, together with the friction calculated from the heat taken up by the oil. The friction is that for the two halves of the bearing pressed together. To get the coefficient of friction, these figures require to be divided by twice the load.

A Heating-System Analysis*

Years ago heating systems were designed so that a minimum back pressure would be exerted on the engine equipment. This was perfectly right then, in the light of the existing knowledge and engineering practice, but since the advent of high-pressure steam distribution and central-station electrical service, the principal reason for the design of this type of system has been removed. A reduction in the back pressure means nothing now, as far as a saving is concerned; in fact, it is actually a loss. It costs money to produce this vacuum; pumps must be operated, and these require power, attention, repairs and renewals; and water must be used to condense the vapor which escapes past the vacuum valves.

Why is it necessary to condense this vapor? The answer usually given travels around in a circle. A vacuum pulls steam through the radiator, water is used to condense this steam to maintain a vacuum to pull more steam through. Your customer buys water to condense the additional steam he should not have been required to buy from you, and then after paying both the steam and water bills, he usually hides his poor judgment by dumping both into the sewer.



THE VACUUM AND PRESSURE SYSTEMS OF HEATING GRAPHICALLY COMPARED

Some of the "old school" will say that a vacuum is necessary in order to free the system of air. Will as much air get into the system with a pressure in the system as with a vacuum, and even if the impossible were possible, is not a push just as good as a pull? The entire question of pressure and vacuum is only a relative one based on the outside air pressure as a reference point, which in many cases has absolutely no connection to the steam in the heating system. What does it matter what happens inside the radiator so long as there is no connection with the outside?

The answer to all this is simple and involves no new principle—all the heat entering with the steam should be used in doing useful work. The radiator should take out all it can and the balance be removed by a cooling coil of some kind. Some of the practical uses to which the excess heat can be put is in secondary radiation, usually known as economy coils, for preheating air in an indirect heating system or for the initial heating of water for domestic and toilet purposes.

The illustration shows a layout that will save from 5 to 20 per cent.

Ohio Engineers Meet at Columbus

The Ohio Society of Mechanical, Electrical and Steam Engineers held its thirty-fourth meeting in Columbus, Ohio, Nov. 16, 1916. The sessions were held in the auditorium of the Ohio Archæological and Historical Society, on the campus of the Ohio State University. This meeting was the fifteenth anniversary, even to the date, of the founding of the society, and so it was quite fitting that, in the absence of the usual presiding officers, the organizer and first president of the society, Elmer E. Miller, of Canton, should be made chairman of the meeting. The first paper presented at the morning session was entitled "Is the Uniflow Type of Engine More Economical Than the Counterflow Type?" by A. C. Ruhl, of Port Clinton, Ohio. From his experience in running both types and from tests upon them he had found the uniflow type more economical, and he preferred to run that type. The second paper was on "Some Experiences of a Boiler Inspector." This was read by the secretary in the absence of the author, Robert J. Huddleson, of Columbus. After lunch a chance was afforded to visit the university power plant, the mechanical and electrical laboratories and

*In connection with central heating, from the Bulletin of the National District Heating Association.

the newly erected shop building. The exhibit of most interest to the visitors was the original working model of the boiler, engine and paddle wheels for the first steamboat, made by John Fitch himself and brought West by his daughter on horseback, over the Allegheny Mountains. At the business session in the afternoon it was voted to have but one session next year, so that the next meeting of the society will be on Nov. 15, 1917, at Columbus. The election of officers resulted as follows: President, William E. Haswell, of Columbus; third vice-president, James H. Debes, of Mt. Vernon; and two managers, Francis C. Caldwell, of Columbus, and Fred K. Schofield, of Zanesville. Proceeding to the papers, the secretary read the one on "The Action of Boiler Water Tubes in Service," as the author, John C. McCabe, of Detroit, Mich., was prevented from attending. Records made automatically by tubes in both Wickes and Stirling boilers showed the frequency and character, in amount and direction, of their movement under the different conditions of running, a maximum movement of ½ in. being obtained. Experiments in the bursting of water tubes under the combined action of heat and pressure were reported. Prof. Horace Judd, Columbus, followed with a talk on "Tests Upon Fire Engines," amply illustrating it by the use of pictures and charts. After a complimentary dinner given by the Columbus members, the reading of papers was resumed. Robert Cramer, of Chicago, spoke upon the "Winslow Safety High-Pressure Boiler" and made liberal use of lantern slides in explaining its construction and possibilities. The combination of this high-pressure boiler with uniflow engines was shown to be a remarkably good one for a power plant. This paper was followed by one on "Automatic Boiler Feed-Water Regulators," by Prof. F. W. Marquis, of Columbus. He divided them into four classes: Float, counterbalanced, expansion-tube and variable vapor-pressure. He showed how those of each class affected the level of water in the boiler, tending to give a fixed-level condition or a variable-level condition. The latter condition seemed to be the better regulation, high-level water for light loads, low-level water for heavy loads and intermediate levels for intermediate loads.

NEW PUBLICATIONS

MANUAL OF INFORMATION FOR STUDENTS

A neat little 22-page pamphlet recently issued by the International Correspondence Schools is intended to explain the methods of the schools and the best mode of procedure for the student in order to obtain the full benefit to be derived from a correspondence course.

One of the points brought out is that the interest of the instructors does not end with the correcting of the papers or answers sent in, but extends all the way from answering questions not contained in the regular study to material assistance in obtaining employment for students when they are considered qualified for it. One of the trite sayings indicating the thorough interest of the school is: "It is our purpose to give every student all the help he needs to get the greatest possible benefit from his course. In order to do this successfully we need to know something about the individuality and surroundings of each student; his temperament, his station in life, his likes and dislikes, his previous training, his ambitions, and so on. You will help us to help you if you will fill out the data sheet so that we can become acquainted with you." Five or six pages of the booklet are devoted to suggestions for study, causes of inability to study and their correction, and the requirements for successful study.- Confidence in the sincerity of intention is engendered by the reading.

THE EFFECTS OF VIBRATION IN STRUCTURES. By Aberthaw Construction Co. Published by the authors, Boston, Mass., 1916. Paper; 6x9 in.; 24 pages.

This booklet is the preliminary report of the Aberthaw investigation of the effects of vibration in structures. This study of vibration and its effects was undertaken with the purpose of determining how it might be eliminated or avoided in building construction. The investigators, realizing the complexity of the problem and the difficulty of tracing the effect to specific causes concerned in vibration of buildings, sent out a large number of inquiries to professional men and manufacturers interested in this subject. This report considers the general aspect of vibration in buildings and gives a digest of the replies to the inquiries sent out. The subject is presented in a very readable form and is illustrated with seismograms showing the effects of vibration in buildings under different conditions. This booklet should prove of value to all who are in any way interested in vibration in structures.

ELECTRIC UNITS AND STANDARDS. Circular No. 60. Published by the Bureau of Standards, Washington, D. C. Size, 6½x10 in.; 68 pages.

This publication gives comprehensive and uptodate information regarding the units and standards in terms of which electric and magnetic measurements are made. It includes the history of the units and the evolution of the definitions upon which the laws on electrical standards are based. The laws of this and other countries are given. These are in substantial agreement, and the various national bureaus of standards coöperate in maintaining the fundamental standards. The circular gives conversion factors, by means of which measurements may be expressed in any desired unit. The information on electric units and standards had not previously been available in a single publication. This paper is now ready for distribution, and those interested in the subject may obtain a copy free by addressing a request to the Bureau.

THE REASONABLENESS AND LEGAL RIGHT OF THE MINIMUM CHARGE IN PUBLIC SERVICES. By S. S. Wyer. Published by the American Gas Institute, 29 West 39th St., New York, 1916. Paper; 6x9 in.; 80 pages. Price, single copy, $1; 25 copies, $20; 100 copies, $50; 500 copies, $200.

The author has presented in a forceful and logical manner the arguments in favor of the "minimum charge." This booklet contains two alphabetical tables, showing the adjudicated and nonadjudicated monetary allowances for minimum charges in existing rate schedules. The necessity of the "minimum charge" to prevent discrimination and compel each class of consumers to pay for the service they are receiving is demonstrated, as well as the fact that there are ample precedents for making the "minimum charge" proportional to the size of the consumer's demand for service. The various decisions underlying these principles are also quoted.

The subject of rates and the establishment of schedules that will prove absolutely fair to all consumers and give a proper return on the investment of the company is one of the most important questions before the industry today.

Every public utility is vitally interested in the facts contained in this paper and should be familiar with the arguments set forth therein. The public they serve should know them as well, that the many erroneous impressions existing today with regard to minimum charges may be corrected.

PERSONALS

Patrick J. Flanagan, of Jersey City, No. 1 N. A. S. E., is now president of the Stationary Engineering School at 2164 Lexington Ave., New York City.

A. C. Schulz, formerly assistant chief engineer of the Locomobile Co., of America, is now chief engineer of the Mercer Automobile Co., Trenton, N. J.

W. J. Ballentine, formerly general superintendent of the Indianapolis works of the Link-Belt Co., has been appointed manager of the Chain Belt Co. at Milwaukee.

B. D. Gray has been elected president of the Hess-Bright Manufacturing Co., Philadelphia, succeeding F. E. Bright, who remains as chairman of the board of directors.

J. N. Oswald has resigned his position as mechanical engineer of the Vacuum Oil Co., to accept that of mechanical superintendent of the American Plate Glass Co., at James City, Penn.

R. H. Stevens, who has been chief engineer of the Midvale Steel Co. and Worth Brothers Co., is now assistant to the general superintendent of the operating department of Worth Brothers Co.

George Alexander, formerly chief engineer of the Atlantic Shore Railway's generating station at Kittery Point, Me., has been appointed chief engineer of the Worcester Electric Light Co., Worcester, Mass.

L. H. Haight, formerly connected with the New York sales office of the Westinghouse Electric and Manufacturing Co., is now the New York sales representative of the Ward Leonard Electric Co., of Mount Vernon, N. Y.

Norman L. Warford, until Nov. 1 in charge of the powdered-coal department of the Anaconda Copper Mining Co., Anaconda, Mont., has become identified with the Powdered Coal Engineering and Equipment Co., of Chicago, in the capacity of engineer in charge of construction. Mr. Warford is credited with having installed the largest powdered coal plants in the United States for the Anaconda Copper Mining Co. at its several works, wherein approximately 1,000 tons of pulverized fuel is burned daily.

OBITUARY

W. L. Kroeschell, secretary of Kroeschell Bros. Ice Machine Co., Chicago, died suddenly on Nov. 23. He was born in Nashville, Tenn., May 22, 1855, but moved to Chicago when a boy. For a number of years he had been a member of the Chicago Board of Trade.

ENGINEERING AFFAIRS

The Compressed Gas Manufacturers' Association will hold its fourth annual meeting at the offices of the Association, 120 Broadway, New York, on Monday, Jan. 15, 1917, at 2 o'clock, followed by the annual dinner at the Manhattan Club.

Col. Whitehead Council, Universal Craftsmen Council of Engineers of Jersey City, N. J., held its annual entertainment and reception at Odd Fellows' Hall on Nov. 21. Dancing followed an enjoyable entertainment. Charles C. Swane was chairman of the arrangement committee.

Elmer E. Chambers Council, No. 5, Universal Craftsmen Council of Engineers held its annual entertainment and ball on November 23 at Palm Garden, New York City. Although the attendance was not as large as heretofore, due to the inclemency of the weather, a pleasant night was spent. A responsive audience greeted the entertainers, and dancing was the concluding feature. The executive committee comprise Edward Northrup, Edward Tompkins, Albert E. Barnes, L. E. Kenney and George E. Quelet.

The American Institute of Steam Boiler Inspectors of New York City held a largely attended meeting at the Engineering Societies Building on Friday evening, Nov. 24, Wilbur S. Wilding, of the International Filter Co., presented a paper on treatment of boiler-feed waters and gave demonstrations of practical methods of determining the presence of corrosive and scale-forming ingredients of raw waters, assisted by Elmer H. Flinn. Mr. Wilding's paper was voted a valuable contribution to the subject of feed-water treatment and will be printed in full by the Institute.

BUSINESS ITEMS

The Midwest Forge and Steel Co. announces its purchase and acquisition of the Heller Forge Works and the Western Forge Co., in East St. Louis, Mo.

The F. Girtanner Co., has been organized by Fred. Girtanner, with offices at 1626 Chemical Building, St. Louis, Mo., to do a general manufacturing and sales business. In addition to marketing the Girtanner improved chain-grate link, the company will represent in the St. Louis and Southwestern district the American Steam Conveyor Corporation, manufacturers of vacuum ash-handling apparatus, and the M. A. Hofft Co., manufacturers of the National Stoker Grate.

TRADE CATALOGS

Ingersoll-Rogler Air Compressors. Ingersoll-Rand Co., 11 Broadway, New York. Form No. 3,130; pp. 24; 6x9 in.; illustrated.

Little David Pneumatic Riveting Hammers. Ingersoll-Rand Co., 11 Broadway, New York. Form No. 8,311; pp. 16; 6x9 in.; illustrated.

Hydraulic Valves and Fittings. The Watson-Stillman Co., 50 Church St., New York. Catalog No. 24; pp. 96; 6x9 in.; illustrated and containing price list.

Moloch Self-Cleaned Under-Feed Stoker. Moloch Stoker Co., Continental & Commercial National Bank Building, Chicago, Ill. Bulletin; pp. 8; 8½x11 in.; illustrated. Describes a new type of underfeed stoker.

The Webster Vacuum System of Steam Heating. A catalog issued by Warren Webster & Co., Camden, N. J., gives a history of their 20 years' experience in vacuum heating. While strictly a catalog, it contains much valuable information on the general subject of heating and on vacuum heating in particular that is well worth reading. This catalog, we understand, is for free distribution on request to the company.

Proposed Construction

Calif., Vallejo—Bids will soon be received by Bureau of Supplies and Accounts, Navy Dept., Washington, for furnishing at Navy Yard, Mare Island, 1,464 malleable iron galvanized unions, Schedule 452; 804 composition unions, Schedule 457, nine 6-in. handy billy pumps, Schedule 452; 8 main air dynamo condenser pumps, Schedule 404; 4 feed water main heaters, Schedule 405; 1,150 lb. condenser tube packing, Schedule 446 and 455.

Idaho, Boise—State Utilities Commission granted E. Goodman permission for electric-light plant on Fayette River.

Ill., Allendale—City plans electric-light plant. A. Greathouse, West Salem, interested.

Ill., Lovington—City plans improving municipal electric-light plant.

Ill., Savanna—Peoples Gas and Electric Co. plans installing 500 kv.-a. turbo-generator. A. P. Woodruff, president.

Ill., Winthrop Harbor—Village Board making plans for electric-light system.

Ind., Marinsville—Home Law Sanitarium Co. plans 3-story, 50x50-ft. power house.

Ind., Sullivan—Wabash Valley Utilities Co., recently incorporated, plans power house. H. E. Vondermart, president.

Iowa, Elma—Consumers Electric Co. plans extending transmission line from Elma to Riceville.

Iowa, Le Mars—C. E. Flaugher, interested in organizing company for electric-light plant.

Kan., Moran—City receiving bids for electric-light plant. About $12,000. W. B. Rollins & Co., 239 Midland Bldg., Kansas City, Mo., engineer.

Ky., Glasgow—Kentucky Utilities Co. purchased site, plans central power plant. H. Reid, Lexington, Pres.

Mass., Boston—Bids will soon be received by Bureau of Supplies and Accounts, Navy Dept., Washington, for furnishing under Schedule 410 at Navy Yard two sets of steam blowers and two evaporators.

Mich., Escanaba—City plans extending municipal electric-lighting system.

Minn., Askove—City plans electric-light system.

Mo., Bowling Green—Bowling Green Mineral Spring Co. plans to install electric-light plant. J. H. Lynch, 625 Locust St., St. Louis, architect.

Mo., Newton—City plans voting on bonds for electric-light plant.

Mo., Trenton—Trenton Gas and Electric Co. plans 75 mi., 26,000 volt transmission line.

Neb., Fremont—City plans improving electric-light plant. About $20,000. C. R. De La Matyr, city clerk.

N. Y., New York—Bids will soon be received by Bureau of Supplies and Accounts, Navy Dept., Washington, for furnishing under Schedule 408, eight marine water-tube boilers, at Navy Yard, Brooklyn.

Okla., Rocky—C. A. Mayhew granted franchise by city to install electric-light plant.

Okla., Verden—City plans to install electric-light plant.

Ohio, Belpre—Council granted Kanawha Traction and Electric Co., Parkersburg, W. Va., franchise for electric-light and power plant in Belpre.

Ohio, Radnor—Bd. Education, Radnor School Dist., receiving bids Dec. 9 for transmission line and transformer station for centralized school buildings. R. W. Jones, clerk.

Ohio, St. Marys—City voted $60,000 bonds for extending and improving municipal electric-light plant.

Ohio, Toledo—It has been announced that Henry L. Doherty & Co., 60 Wall St., N. Y., is working on plans for a new central station for Toledo to meet the increasing power demands of that city. The estimated outlay on the new station is said to be about $6,000,000 and the ultimate capacity over 100,000 kw.

Ohio, Warren—Trumbull Public Service Co. plans to remodel its plant.

Penn., Annville—H. E. Millard plans electric-power plant.

Penn., Philadelphia—Bids will be received by Bureau of Supplies and Accounts, Navy Dept., Washington, until Dec. 12 for furnishing at Navy Yard under Schedule 400, two 10,000-gal. storage tanks.

R. I., Pawtucket—Jencks Spinning Co. plans 100x100-ft., brick power plant on Weedon St.

Tenn., Arlington—City plans electric-light plant. About $10,000. W. A. Taylor, Mayor.

Tex., Brady—City plans to improve electric-light plant.

Tex., Forney—Texas Light and Power Co. plans extending its power transmission line; also street lighting system. E. Oram, electric engineer.

Tex., Nordheim—Texas Southern Electric Co. plans extending power transmission line; also electric-light system.

Tex., Streetman—Corsicana Gas and Electric Co. applied to Council for franchise for electric-light and power plant. J. Carpenter, general manager.

Tex., Valley View—City plans electric-light plant.

Utah, Brigham—City plans voting on $10,000 bonds for rebuilding electric-light plant.

Vt., Salisbury—Addison Electric Co. making plans for hydro-electric plant.